Advances in Urban Wet Weather Pollution Reduction

June 28 – July 1, 1998
Renaissance Cleveland Hotel
Cleveland, Ohio U.S.A.

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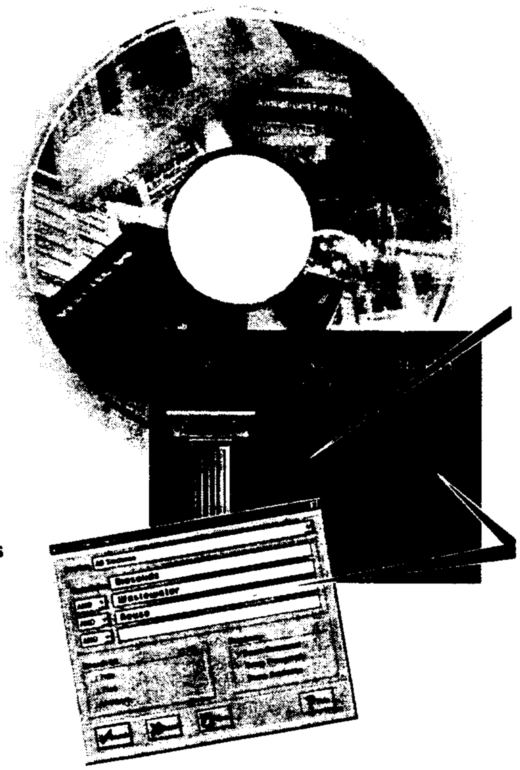

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PROCEEDINGS

ADVANCES IN URBAN WET WEATHER POLLUTION REDUCTION

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CONTENTS

Session 1 **OPENING GENERAL SESSION**
(PAPERS NOT REQUESTED)

Session 2 **EFFICIENT USES OF COLLECTION SYSTEMS (EXISTING AND PROPOSED)**

CSO Relocation to Protect Sensitive Use Area and Comply With CSO Control Policies
David A. Kubiak, Massachusetts Water Resources Authority; Gregory R. Heath, Daniel Donahue, Donald Walker 1

Cost Effective CSO Reduction: Maximizing Wet Weather Flow to the POTW
Peter Young, Hazen & Sawyer; Robert Smith, Robert Gaffoglio, Les Kloman 11

Inline Storage With And Without Real Time Control
George Rempel, TetrES Consultants Inc.; E. Sharp, N. Szoke, D.M. Morgan 17

Assessment of the Effectiveness of a Wet Weather Storage/Treatment Facility
Foster McMasters Jr., Metcalf & Eddy, Inc.; David R. Bingham, Frank Greenland, Tina Wolf 27

Storage/Sedimentation Facilities for Control of Storm and Combined Sewer Overflows:Design Manual
Joyce Perdek, U.S. EPA; Shih-Long Liao, Mary Stinson, Richard Field 41

Session 3 **VARIETIES OF WET WEATHER MODELING APPLICATIONS**

Computer Modeling for Design and Practical Purposes
Sean P. Murphy, Monroe County Pure Waters; Salvatore A. LaBella, James Matzat 49

Impacts of Seasonally Varying Model Parameters on Predicting Combined Sewer Overflows
Mark TenBroek, Camp Dresser & McKee; Benjamin J. Sherman, Philip Brink, Gary Fujita 55

Development of a Complex Integrated Model of the Baton Rouge City / Parish Pressurized and Gravity Wastewater Collection System
Neil R. Moody, Montgomery Watson; Clinton Cantrell 65

Combined Sewer System: To Separate...Or...Not To Separate
Taymour El-Hosseiny, EMH&T; Gary W. Gilbert, Laurie A. Mehl 73

Simulating Infiltration and Inflow in Sewer Systems
Using SWMM RUNOFF
Paul Kadota, Greater Vancouver Regional District;
Yassine Djebbas ... 83

Session 4 **INTERACTIVE SESSION: THE NORTHEAST OHIO REGIONAL SEWER DISTRICT WET WEATHER PROGRAMS**

Historical Perspective
Kenneth A. Pew, Northeast Ohio Regional Sewer District ... 93

Wet Weather Plant Operation
Lewis Debevec, Jr., Northeast Ohio Regional Sewer District ... 95

In-Line Storage of Wet Weather by Real-Time Control
Daniel M. Hudson, Northeast Ohio Regional Sewer District ... 103

Combined Sewer System Best Management Practices
Robert D. Gow, Northeast Ohio Regional Sewer District ... 107

Interceptors & Biofilters
Richard J. Switalski, Northeast Ohio Regional Sewer District ... 113

Brick Masonry Sewer Rehabilitation Using Slip Line Method
Rodney J. Dell'Andrea, Northeast Ohio Regional Sewer District ... 119

Northeast Ohio Regional Sewer District CSO/Watershed Planning
Frank P. Greenland, Northeast Ohio Regional Sewer District ... 123

Community Discharge Permit Program
Jeffrey E. Duke, Northeast Ohio Regional Sewer District ... 129

Current Water Quality Conditions in the Greater Cleveland Area
James F. Weber, Northeast Ohio Regional Sewer District ... 133

Consideration for the Future
Kenneth A. Pew, Northeast Ohio Regional Sewer District ... 139

Session 5 **EMERGING TECHNOLOGIES IN WET WEATHER CONTROL**

Innovative Multi-chambered Stormwater Control Device
for Critical Source Areas
Robert Pitt, University of Alabama at Birmingham;
Brian Robertson, Richard Field ... 141

High - Rate Disinfection Technologies for Wet Weather Flow (WWF)
Mary K. Stinson, U.S. EPA; Richard Field, Peter Moffa,
S. Goldstein, E. Delva, Eric Delva ... 151

The Effectiveness of Freshwater Wetlands for Nonpoint
Source Pollution Control in the Rouge River Watershed
Douglas Denison, JJR Incorporated; Donald L. Tilton ... 157

CSO Controls and Supplemental Aeration for Paerdegat Basin
Todd R. Peterson, Hazen & Sawyer; R. Smith, R. Gaffoglio,
L. Kloman, T. Comastro, W. Leo, W. McMillin 167

Urban Runoff Filtration for Critical Source Areas
Shirley Clark, University of Alabama at Birmingham;
Robert Pitt, Richard Field, Richard Scholze 177

Session 6 **GIS THE KEY TO INFORMATION MANAGEMENT**

Technology in the Sewer Business
Joe Castillo, Woolpert LLP; Lisa Martin,
Drew Ackerman 187

I / I Evaluation and Rehabilitation Program Simplified
with Cost-effective GIS Implementation
Dan R. Hegwald, Wade & Associates, Inc.; Ray Chao,
John Bergin, Jody Zobolio, Peter Fu 195

Parris Island AM/FM/GIS
Ronald S. Lynn, RJN Group, Inc. 203

Relational Database System for In-Sewer and CSO Monitoring
Martin Tremblay, Asseau BPR; Helene Charest,
Elise Villeneuve 211

A Desktop GIS/Hydraulic Modeling Application for SSO
Reduction
Rod Moeller, Montgomery Watson; Jeff Sapia 221

Utilization of GIS in Hydraulic Model Building Provides
Numerous Benefits
Gerald T. Preau, Sewerage and Water Board of New Orleans;
Robert Armstrong, Martin T. Dorward 227

Session 7 **DEVELOPING WET WEATHER WATER QUALITY STANDARDS**

Wet Weather Standards and Their Role in Clean Water
Act Compliance
David Evans, McQuire, Woods, Battle and Boothe 237

Session 8 **ASSESSING SOURCE AND FLOTABLES CONTROL**

Boston Water and Sewer Commission Finds Separation to
be the Appropriate Level of Control
Paul W. Keohan, Boston Water & Sewer Commission 239

Constructed Wetlands Balance Urban Wet Weather Challenges
Thomas M. Evans, URS Greiner 247

In-Line Storage With And Without Real Time Control
Nicholas T. Szoke, TetrES Consultants Inc.; E. Sharp, R. Rempel
D. M. Morgan 257

Catch Basins — Effective Floatables Control Device
Gary M. Grey, HydroQual Inc.; Frank Oliveri 267

Evidence of a Critical Velocity in Underflow Baffle Design for Floatables Control in Combined Sewer Overflows (CSOs)
Martin Couture, John Meunier Inc.; John Cigana,
Giscard Lefebvre, Claude Marche 275

Session 9 **MANAGING URBAN WET WEATHER SYSTEMS**

Westerly District Interceptors-Inspection and Evaluation Project Benefits and Lessons Learned
Jeffrey Duke, Northeast Ohio Regional Sewer District;
Graham Knot 283

Stormwater Utilities — Key Components and Issues
Amy Doll, Apogee / Hagler Bailly Inc.; Rick Albani,
Greg Lindsey 293

Wet Weather Flow Control Planning for Great Lakes Cleanup
Donald G. Weatherbe, Donald G. Weatherbe Associates, Inc;
Sandra Kok 303

Public Involvement Strategies for Urban Communities
William L. Hurt, PR Networks, Inc. 313

Success Achieved in Reducing Sanitary Sewer Overflows Using the Program Management Approach
Rosanne Cardozo, Montgomery Watson; Anthony J. Clemente,
William M. Brant 323

Session 10 **ABCs OF FIELD DATA COLLECTION**

Calculating Inflow in Complex Hydraulic Networks with Pumped Flow Inputs and By-passes
John S. Gresh, RJN Group, Inc.; Frank T. Terre 329

An Intensive Field Sampling Program in Support of a Numerical Toxicant Fate and Transport Model and Risk Assessment of The Duwamish River and Elliot Bay, Washington
Randy Shuman and Scott Mickelson, King County Dept of Natural Resource; K. Schock, S. Munger, L. Wharton, J. Strand, K. White 337

R0024761

Seasonal Characterization of Stormwater Quality in an Urban Residential Area
Amy M. Schofield, Boston Water and Sewer Commission; Lisa Eggleston 347

Water Quality Monitoring for the Determination of Effects of Collection System Discharges on Receiving Waters
Eric M. Harold, Montgomery Watson; Greg Stacy, Jessica Belcher, Clinton Cantrell 357

Dye Dilution Testing in the Greater Detroit Regional Sewer System
Timothy J. Dekker, Camp Dresser & McKee; Mark TenBroek, Rashila Karsan 367

Session 11 **SSES/REHABILITATION: CHOICES AND IMPLEMENTATION**

Is Comprehensive Rehabilitation for I / I Reduction Cost Effective in Houston?
Michael J. Bagstad, Montgomery Watson; Yeh-Min Maa, William H. Sukenik, Gisa M. Ju 377

Test Basins for I / I Reduction and SSO Elimination
Peter Keefe, ADS Environmental Services 385

The Inspection of Surcharged Sewers Using Sonar Technology
Gerald T. Preau, Sewerage & Water Board of New Orleans; Alan McCloskey, Sal Ahmad 395

Basement Flooding - Salem Oregon's Experience
Kenneth L. Roley, City of Salem; Randy Pecor, Jim Long 407

Oakland Ravine Stormwater Treatment System Project - Borough of Queens, NYC
Ralph E. Dinkle, URS Greiner; Les Kloman, Harvey Thomas 417

Tulsa Addresses Sanitary Sewer Overflows
C. Wayne Dillard, Burns & McDonnell; Robert Shelton, Nam Nguyen 427

Session 12 **RECEIVING WATER ISSUES**

Combined Versus Separate Sewers for Future Developments; A Case Study in Montreal
Alain Charron, Asseau - BPR; Mohamad Osseyrane, Jean-Nicolas Simoneau, Yves Charron 435

Simulating Water Quality in the Duwamish Estuary and Elliott Bay: Comparing Effects of CSOs and "Other Sources"
Kevin Schock, King County Dept of Natural Resource; R. Shuman, Zhong Ju, Bob Swamer, Sydney Munger, John Hamrick 443

Coordination With State Water Quality Standards During Development of a Long - term CSO Control Policy
Michael Hornbrook, Metcalf & Eddy, Inc.; Daniel Donahue, Cheryl Breen, Donald Walker 453

The Doan Brook Watershed Study Progress Report: Development of an Effective Quality Assurance Project Plan
Michael E. Hulley, XCG Consultants, Ltd.; Roy Rudolph, Harold Chard, Betsy Yingling 463

Wet Weather Pollution Effects on Water Quality in Curm Creek
Frank Dowman, Crum-Ridley Chester Creek Volunteer Monitors; Arthur E. McGarity, Sonja Downing 473

Questions and Answers for Short Term Flow Monitoring Programs
Alan J. Hollenbeck, RJN Group 483

Session 13 **INTERACTIVE PANEL: STORMWATER PHASE II PERMITTING**

Expanding the Coverage of the NPDES Storm Water Program: The Proposed Phase II Rule
John A. Kosco, U.S. EPA Office of Wastewater Management 489

Session 14 **MODELING FOR THE REAL WORLD**

Efficient/Effective Data Collection Program Yields a Reliable Hydraulic Model
Gregory Anderson, Woolpert LLP; Lamont Curtis 495

Optimization of Off-line Storage Tank Operation Using Real Time Control Modeling
Neil R. Moody, Montgomery Watson; Andrew Baldwin 501

Using Real Time Controls to Explore Alternatives to Relief Sewer Construction
Bradley T. Pierce, Applied Geographic Technologies, Inc; Preston Dillard, Quo-Ching "Peter" Fu 511

Real Time Control Modeling for Sewer System Optimization
Mike N. Agbodo, Black & Veatch; Richard E. Nelson 521

Demystifying Some Aspects of Real Time Control Applications From the Design Phase to Implementation
Hubert Colas, Asseau BPR; Denis Simard, Pierre Lavallee, M. Pleau, Martin Tremblay, Charles Meunier 531

Wet Weather Modeling for a Large Wastewater Collection System
Fernando F. Gonzalez, City of Los Angeles; J. Randy Price 541

Session 15 **WET WEATHER DISCHARGE**

Ile-de-France Central Region Dry and Wet Weather Wastewater Study Using a Watershed Approach
Pierre Lavallee, BPR Group; Jacques Sicard, Michel Affholder, F. Valiron, Richard Dartout, Sophie Bedard, Hubert Colas 551

Use of the Watershed Management Approach to Reduce the Impact of Combined Sewer Overflows and to Address Storm Water Phase II "Donut Holes"
Geoff Brosseau, City & County of San Francisco; Daniel Rourke 561

Development of the MWRA Long-term CSO Control Plan Using the Demonstration Approach
Gregory R. Heath, Metcalf & Eddy Inc.; Donald E. Walker, Michael J. Hornbrook, Cheryl Breen, Daniel W. Donahue 571

Combined Sewer Overflow Study in Cleveland's Westerly District
David R. Bingham, Metcalf & Eddy Inc.; Gina Beim, Angelika Forndran 581

CSO Plan Optimization
Hubert Colas, Asseau-BPR; Martin Pleau, Elise Villeneuve 591

Session 16 **URBAN STREAMS — WILL WET WEATHER CONTROL WORK?**

Experiences with Urban Stream Quality Management
Nancy Schultz, CH2M HILL 601

The Urban Stream Use Designation: A Step Towards Improved Management
Lester A. Stumpe, Northeast Ohio Regional Sewer District 603

Assessing the Condition and Status of Aquatic Life Designated Uses in Urban and Suburban Watersheds Using Biological Assessments
Chris Yoder, Ohio EPA 613

R0024764

CSO RELOCATION TO PROTECT SENSITIVE USE AREA AND COMPLY WITH CSO CONTROL POLICIES

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David A. Kubiak, Massachusetts Water Resources Authority
Daniel W. Donahue, Metcalf & Eddy, Inc.
Donald E. Walker, Metcalf & Eddy, Inc.

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ABSTRACT

The 12,000-foot long, 11-foot diameter North Dorchester Bay consolidation conduit will provide complete capture of overflows from seven combined sewer overflow (CSO) outfalls tributary to Dorchester Bay and the bathing beaches of South Boston (Figure 1). The conduit will be sized to capture the peak flow hydraulically feasible at the seven CSOs and convey the flow to a dedicated CSO facility at its downstream end. The CSO facility will provide coarse screening, effluent pumping, fine screening, disinfection, and dewatering for flows collected by the consolidation conduit. Flow up to the available storage capacity in the conduit will be pumped back to the interceptor system at the end of each storm, and flow above the storage capacity will be treated by the CSO facility prior to discharge into the Reserved Channel.

Even with the complete elimination of CSO discharges, water quality violations were still predicted along the South Boston bathing beaches. It was determined that the North Dorchester Bay consolidation conduit and the Reserved Channel CSO facility could be sized to capture separate stormwater tributary to the CSO outfalls downstream of the CSO regulators without significantly affecting the project cost. The capture of separate stormwater was determined to cost-effectively increase the water quality benefits of the project.

INTRODUCTION

In July 1997, the Massachusetts Water Resources Authority (MWRA) completed facilities planning for controlling CSOs in the Greater Boston area in accordance with state and federal CSO policies and in compliance with a federal court schedule. MWRA's CSO control plan consists of 25 projects, including the North Dorchester Bay consolidation conduit. This project will eliminate seven CSOs which currently discharge to North Dorchester Bay, along the most extensive bathing beaches in Boston. The North Dorchester Bay receiving water segment supports both swimming and shellfishing, which are considered critical uses under the Massachusetts Department of Environmental Protection (DEP) CSO control policy. This policy requires that CSOs be eliminated from critical use areas unless it is infeasible to do so. The North Dorchester Bay CSO relocation project will eliminate CSOs without creating the increase in stormwater discharge and the continued violations of bacterial water quality standards that would be associated with sewer separation. Instead, this project will also provide the means to control pollution from separate stormwater that is currently tributary to the CSO outfalls downstream of the CSO regulators without a substantial increase in project cost.

Implementation of the MWRA's CSO control plan is currently underway, with projects now in design or in construction. Several smaller projects have already been completed. Design of the North Dorchester Bay consolidation conduit began in August, 1997. Construction is currently scheduled to begin in February, 2000, about seven months ahead of the court-mandated construction start date. Construction is scheduled to be completed in early 2003. The estimated capital cost of the North Dorchester Bay consolidation conduit, including the downstream CSO facility and other related features, is $140 million. The MWRA's financial commitment to this project and aggressive project schedule clearly demonstrate the Authority's dedication to fulfilling court-ordered requirements for CSO control in accordance with applicable regulatory requirements and in an environmentally responsible manner.

This paper presents pertinent project background, identifies the CSO control alternatives considered, and focuses on the development of the recommended alternative for elimination of CSO discharges from North Dorchester Bay.

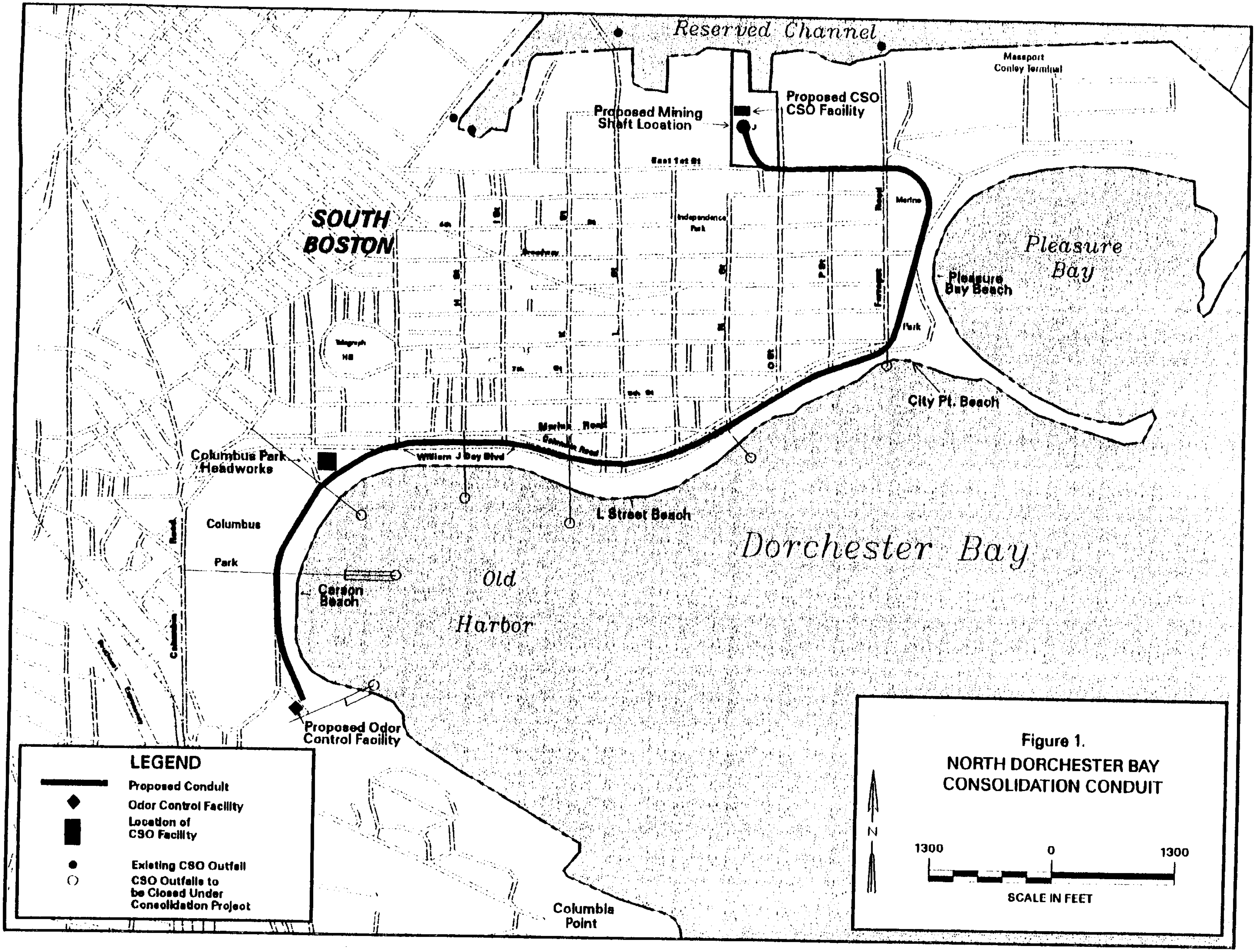

Figure 1.
NORTH DORCHESTER BAY
CONSOLIDATION CONDUIT

PROJECT BACKGROUND

The North Dorchester Bay CSO relocation project was developed based on an understanding of the features and uses of the receiving water segment, an in-depth understanding of the wet weather operation of the combined sewer system in the project area, and the regulatory framework established by the Massachusetts and national CSO control policies.

Receiving Water Segment

The North Dorchester Bay receiving water segment extends from the mouth of the Reserved Channel to Columbia Point in Dorchester. This area is classified as SB-Fishable/Swimmable with restricted shellfishing in approved areas. Massachusetts DEP-designated critical uses for this receiving water segment include swimming and shellfishing. Existing water-based uses within this area are primarily recreational and include power boating and sailboarding, swimming, and fishing. Although the Division of Marine Fisheries has identified a significant shellfish resource in the Carson Beach area, shellfishing is currently prohibited due to the fecal coliform levels in the overlying waters and the proximity of the CSOs. Pleasure Bay also contains shellfish beds, which are currently closed for management reasons.

Many of the land uses along the shore of this receiving water segment support water-based recreational uses. The Metropolitan District Commission, a state agency, controls much of the waterfront in this area, although certain parcels are controlled by the city of Boston or by private water-based interests. Much of the waterfront is used for passive recreation, and a number of separate beach areas, some including bathhouse facilities, are located in this area. Immediately inland is the densely developed residential neighborhood of South Boston.

The seven CSOs which currently discharge to North Dorchester Bay are the predominant source of fecal coliform bacteria during larger storms, such as the 1-year, 24-hour storm event. Although the average concentration of fecal coliform bacteria in stormwater is substantially less than the concentration in CSO, the total annual volume of stormwater discharged to North Dorchester Bay is substantially greater than the annual volume of CSO. Approximately 85 percent of the storms that occur in a typical year do not cause CSO discharges to North Dorchester Bay, but do generate stormwater discharges. In terms of other pollutants, such as biochemical oxygen demand (BOD), total suspended solids (TSS), nutrients, and toxics, pollutant loadings from stormwater appear to be substantially greater than the loads from CSOs.

System Understanding

Several methods were applied to gain an understanding of the configuration and performance of the combined sewer system. These included a careful review of system plans and record drawings, field inspections, flow monitoring, and detailed sewer system modeling. For this project, the EXTRAN block of the U.S. EPA Stormwater Management Model (SWMM) was used to predict system response to specific design storm events and to assess a range of CSO control alternatives.

A total of 11 CSO regulators provide relief of the local combined sewer system and interceptors through the seven CSO outfalls tributary to North Dorchester Bay. On an annual basis, the CSOs discharge about 34,000 m^3 (9 million gallons) of combined sewage. Activation frequencies among the seven outfalls range from a low of four discharges per year to a high of 15 per year.

The interceptor network serving the 11 North Dorchester Bay CSO regulators is presented schematically in Figure 2. All of the interceptors associated with the regulators, the South Boston Interceptor (SBI) South and Main Branches, the Dorchester Interceptor, and the Boston Main Interceptor (BMI), are tributary to the Columbus Park Headworks. This headworks directs flow into a deep rock tunnel for conveyance to the MWRA Deer Island wastewater treatment facility. The headworks capacity is 8.1 m^3/sec (185 mgd), and typical dry weather flows are about 2.2 m^3/sec (50 mgd), indicating that substantial capacity is available for conveyance of wet weather flows to Deer Island. Since the headworks capacity matches available capacity in the deep rock

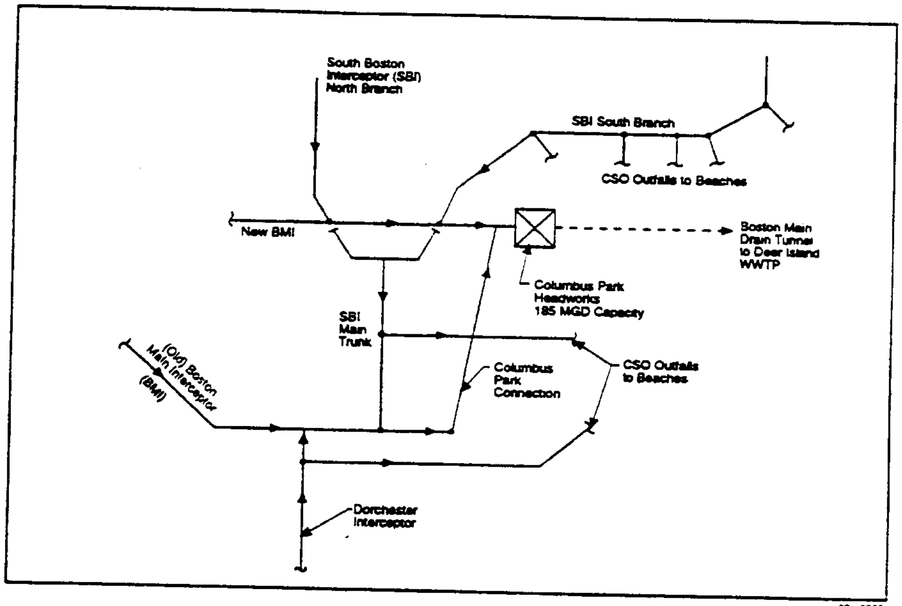

FIGURE 2. SCHEMATIC OF INTERCEPTORS TRIBUTARY TO THE COLUMBUS PARK HEADWORKS

tunnel and at the Deer Island treatment facility, increasing the wet weather capacity of the headworks would not be possible without construction of a new deep rock tunnel and increased treatment capacity at Deer Island.

In smaller storms, much of the combined sewage is captured and conveyed to Deer Island for secondary treatment. During a 3-month, 24-hour storm, the capacity of the Columbus Park Headworks is exceeded, and the headworks must be choked to limit its influent flow to 8.1 m^3/sec (185 mgd). This choking causes surcharging in the South Branch of the SBI, but not in the other interceptors serving the North Dorchester Bay CSOs. In larger storms, such as the 1-year, 24-hour storm, choking at the headworks causes substantial surcharging in all of the interceptors, affecting all of the area CSOs.

This system understanding enabled the following conclusions to be drawn:

- North Dorchester Bay CSOs that activate infrequently (e.g., 4 to 6 times per year) are most likely influenced by interceptor surcharging which results from relatively large storm events.
- North Dorchester Bay CSOs that activate more frequently (e.g, 11 to 15 times per year) are likely affected by local hydraulic restrictions.
- Alternatives based on interceptor relief would not control the North Dorchester Bay CSOs in storm events greater than the 3-month to 1-year, 24-hour storm, due to capacity limitations at the Columbus Park Headworks, the deep rock tunnel to Deer Island, and the Deer Island treatment facility.

This system understanding was necessary to define and evaluate CSO control alternatives for the North Dorchester Bay CSOs, as discussed below.

Regulatory Framework

In addition to understanding the features and uses of the receiving water segment and the wet weather operation of the combined sewer system, an understanding of the regulatory framework established by the

Massachusetts and national CSO control policies was important in developing appropriate control alternatives for the North Dorchester Bay CSOs.

Under the Massachusetts policy, CSO elimination must be considered during the development of CSO control plans for all receiving waters, and CSO elimination is stressed for critical use receiving waters that support swimming and shellfishing, such as North Dorchester Bay. The policy identifies both sewer separation and CSO relocation as technologies for eliminating CSO discharges from critical use areas.

The national CSO control policy also emphasizes CSO elimination in sensitive areas, which include waters that support primary contact recreation. Similar to the Massachusetts policy, the national CSO control policy requires that overflows to sensitive areas be controlled by elimination or relocation wherever physically possible and economically achievable, except where elimination or relocation would provide less environmental protection than additional treatment.

ALTERNATIVES EVALUATION

A broad range of alternatives was considered for the elimination or control of CSO discharges to North Dorchester Bay. The evaluation of CSO control alternatives involved a series of screening steps. Using preliminary hydraulic evaluations, system knowledge, and knowledge of the on-shore and water-based uses of the receiving water segment, certain alternatives were eliminated from further consideration without developing detailed cost and performance data. These included the following:

- Local sewer separation. Sewer separation upstream of only the seven North Dorchester Bay CSO outfalls did not eliminate CSO discharges during the 1-year, 24-hour storm, due to interceptor surcharging and backwater from choking at the Columbus Park Headworks.

- Individual treatment or storage facilities for each outfall. It did not appear to be cost-effective or feasible to site and construct seven separate facilities in a densely populated area featuring heavily used parks and beaches.

- Outfall consolidation to treatment. All of the outfall consolidation alternatives had sufficient storage volume in the conduit to capture the 1-year, 24-hour storm volume, suggesting that treatment processes would operate very infrequently.

For alternatives that passed the initial screening step, information on cost, performance, construction risk, public acceptance, water quality, construction-related impacts, and long-term environmental impacts was developed and assessed. This information was developed for the following alternatives:

- Consolidated near-surface storage conduit. This alternative involved constructing a consolidation conduit, sized for the 1-year or 3-month, 24-hour storms to capture North Dorchester Bay CSOs up to the available conduit storage volume. Captured CSOs would be pumped back to the interceptor system following each storm event. CSOs in excess of the conduit volume would discharge untreated via the seven existing North Dorchester Bay CSOs.

- Interceptor relief with local controls at three CSO outfalls. This alternative involved constructing a new interceptor parallel to the South Branch of the SBI. The relief interceptor was predicted to eliminate CSO discharges at all but three North Dorchester Bay CSO outfalls in the 1-year, 24-hour storm, and local storage and/or system optimization measures would be implemented to control the relatively minor discharges at the three outfalls remaining active. CSOs in larger storm events would continue to be discharged untreated via the seven existing North Dorchester Bay CSOs.

- CSO elimination by system-wide sewer separation. Sewer separation of all combined sewer areas tributary to the Columbus Park Headworks was predicted to eliminate CSO discharges from the seven North Dorchester Bay CSOs.

- CSO relocation to Reserved Channel. This alternative involved a consolidation conduit running along the South Boston beaches to a CSO facility located along the Reserved Channel. The conduit and CSO facility would be sized to convey the maximum peak flow hydraulically capable of reaching the conduit from the CSO regulators tributary to the seven North Dorchester Bay CSOs. The CSO volume stored in the conduit would be returned to the interceptor system by pumping following each storm event.

The alternative to relocate CSOs from North Dorchester Bay to the less-sensitive Reserved Channel was determined to be in compliance with the Massachusetts and national CSO control policies based on the characteristics and land-based uses of the Reserved Channel. The Reserved Channel supports deep water container shipping and cruise ship access into the Port of Boston. In addition, it supports a bulk fuel delivery, storage and distribution operation. These uses preclude the use of the Reserved Channel for primary contact recreation and shellfishing, and limit opportunities for passive recreation. On this basis, the Reserved Channel was considered to be less sensitive than North Dorchester Bay, and CSO relocation was considered to be an appropriate option for eliminating CSO discharges to North Dorchester Bay.

Based on cost-performance evaluations, the initially preferred alternative was interceptor relief with local controls at three CSO outfalls. This alternative would not, however, achieve the goal of CSO elimination in the critical use area of North Dorchester Bay. Of the two alternatives that would eliminate CSO discharges, CSO relocation was determined to be preferable as compared to system-wide sewer separation. Sewer separation would have involved extensive construction impacts in densely populated, residential areas, and the area required to undergo sewer separation would have extended beyond the area tributary to the North Dorchester Bay CSOs. Sewer separation would also have significantly increased the fecal coliform bacteria load to North Dorchester Bay due to the increased stormwater volume. This result would be inconsistent with the national CSO policy, which requires CSO elimination in sensitive areas except where elimination would provide less environmental protection than other alternatives. While the relative impacts and health risks associated with fecal coliform bacteria from stormwater versus CSO origins can be debated, it is clear that as long as fecal coliform bacteria remains the indicator species used to measure compliance with the swimming standard, the standard would continue to be violated if sewer separation were implemented. In contrast, CSO relocation would capture all of the overflow from the 11 North Dorchester Bay CSO regulators and either store it or relocate it to the less sensitive Reserved Channel. For these reasons, CSO relocation was selected as the preferred alternative.

DEVELOPMENT OF PREFERRED ALTERNATIVE

Following selection of the preferred alternative, the CSO relocation concept was further developed. This process involved establishing peak design flows, evaluating conduit construction and lining alternatives, developing technologies for conduit ventilation and odor control, and determining appropriate pumping and treatment technologies for the CSO facility. In addition, a formal process was followed to evaluate and compare alternative routes for the consolidation conduit and alternative sites for the CSO facility.

Design Flows

The peak design flow for the consolidation conduit and CSO facility was assessed by determining the peak flow hydraulically feasible at each of the 11 regulators associated with the seven North Dorchester Bay CSO outfalls. Curves of peak flow versus storm recurrence interval were plotted for each regulator to establish the flow rate at which increasing the storm size did not substantially increase the peak flow. The peak flows, representing the ultimate delivery capacity of the tributary combined sewer system, were generally attained for the 25-year, 24-hour storm, although peak flow was essentially reached at some regulators by the 10-year, 24-hour storm.

To establish the maximum rate of flow in the consolidation conduit, the relationships among timing of peak flows at the individual regulators, travel time in the conduit, and volume of flow in the conduit were evaluated. Since the peak flow into the conduit would occur after the conduit had filled, minimal attenuation of peak flows would occur. The peak flows in the consolidation conduit over a range of storm recurrence intervals are presented in Figure 3. Based on the peak flow of approximately 22.3 m^3/sec (510 mgd) derived from this analysis, an 11-foot diameter conduit at a slope of 0.001 was selected.

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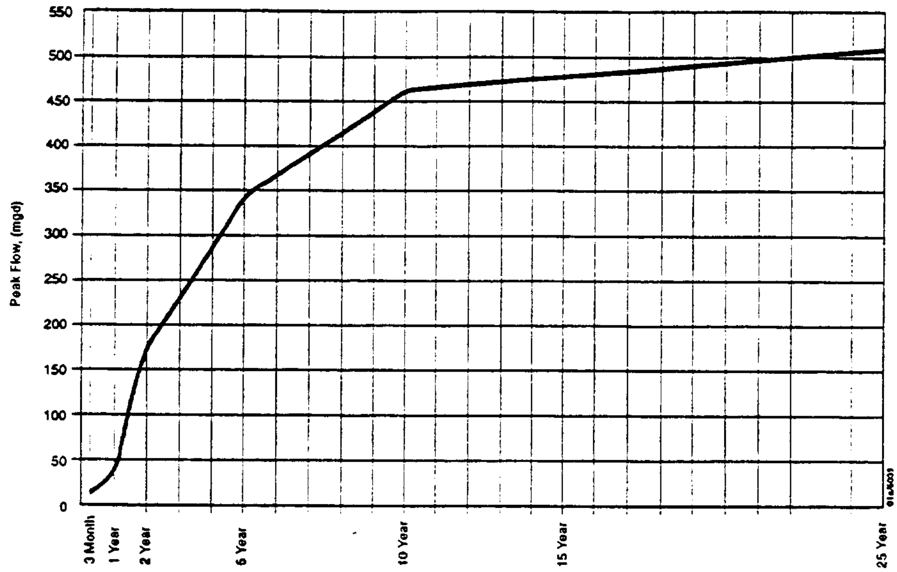

FIGURE 3. PEAK FLOW VS. DESIGN STORM IN THE DOWNSTREAM REACH OF THE NORTH DORCHESTER BAY CONSOLIDATION CONDUIT

With the exception of approximately 24 hectares (60 acres) of separate storm drainage tributary upstream of certain CSO regulators, storm drainage tributary to the seven North Dorchester Bay CSO outfalls enters downstream of the regulators and would continue to be discharged following project completion. Receiving water analyses determined that the continued discharge of separate stormwater would result in violations of the bacteria standard for swimming on a regular basis. Given the critical uses in this receiving water segment, an assessment of the impact of capturing stormwater tributary to the North Dorchester Bay CSO outfalls downstream of the CSO regulators was conducted. Using the same type of analysis described above for assessing peak CSO-only flows, the peak flow of CSO plus separate stormwater tributary to the consolidation conduit was determined to be about 26.3 m^3/sec (600 mgd). This flow rate represented an increase of about 4 m^3/sec (90 mgd) as compared to the CSO-only peak flow, and it was determined that the 11 foot diameter conduit at a slope of 0.001 would be adequate to convey the 26.3 m^3/sec (600 mgd) peak flow. It was also determined that the increase in firm pumping capacity at the CSO facility could be achieved by changing the pump impeller. Based on these assessments, a relatively minor incremental increase in project cost and complexity would be associated with capturing separate storm drainage tributary to the North Dorchester Bay CSO outfalls. Given the critical uses of this receiving water segment, these changes appeared to be justified and the capture of separate stormwater was incorporated into the project.

Conduit Construction Alternatives

Based on hydraulic requirements of the project and available information on local geology, the consolidation conduit was recommended to be constructed in soft ground, as opposed to being constructed in bedrock. The CSO outfalls to be connected to the consolidation conduit are located at relatively shallow depths, and can be readily intercepted by a soft ground tunnel. In the project area, the approximate depth to competent bedrock is greater than 30.5 m (100 ft). A deep rock tunnel would have increased the cost and complexity of appurtenant features such as dropshafts and the pumping components of the CSO facility.

The presence of both soft clays and relatively clean sand and gravel deposits along portions of the conduit alignment, and proximity to North Dorchester Bay dictated that a closed-face tunnel boring machine (TBM) be used to avoid groundwater-related instability. In addition, groundwater contamination involving floating product was encountered along a portion of the alignment. A closed-face TBM represented an effective approach to prevent the drawdown of contaminated groundwater into the tunnel horizon. Open cut construction was not considered to be feasible due to existing development in the project area, as well as construction-related difficulties of maintaining a trench at depths of 7.6 to 18 m (25 to 60 ft) through the soil and groundwater conditions described above. Open face mining techniques were also considered to be infeasible due to the anticipated soil and groundwater conditions.

Conduit Lining Alternatives

A precast concrete bolted and gasketed segmental lining system was recommended for the North Dorchester Bay consolidation conduit over other lining technologies. The anticipated soil and groundwater conditions necessitated the installation of a water-tight liner both for construction and long-term operation. During construction, a water-tight liner was deemed necessary to prevent tunnel instability and groundwater inflow. Since CSO storage in the consolidation conduit is an important project feature, a water-tight liner, which would enable the conduit to remain empty between storm events, was a key project requirement. Other lining technologies considered did not offer the advantages of a precast segmental lining system. A jacked pipe lining was considered, but would have required the installation of shafts at all changes in direction and at distances as required to prevent excessive jacking loads. The precast segmental lining system could be installed along horizontal radii, and would not require intermediate shafts. These features were advantageous given the densely developed character of the project area, where sites for shafts are extremely limited. A cost comparison indicated that the precast segmental liner would be about $10 million less expensive than jacked pipe. This cost comparison also supported selection of the precast segmental liner system.

Conduit Ventilation and Odor Control

An activated carbon odor control system and exhaust fans at the upstream end of the consolidation conduit were recommended to provide conduit ventilation and odor control. The system would consist of two dual-bed

carbon adsorption units, centrifugal fans, ductwork, and isolation dampers. This equipment would be housed within an above ground visual screen. The visual screen would be attached to a small above-ground building housing mechanical and electrical equipment.

Conduit Route Alternatives

The first step in the route selection process was to identify a wide corridor through which the consolidation conduit could pass. Since the purpose of the conduit is to intercept overflows from the seven CSOs tributary to North Dorchester Bay, the corridor was defined by the distance between each CSO regulator and the downstream terminus of each CSO outfall. This corridor was divided into an upstream, middle, and downstream reach, and specific route alternatives were then defined for each reach. Route alternatives were generally confined to public rights-of-way or open areas such as park land and the beach. Routes under buildings or other structures were avoided because of the potential for ground settlement or heave during conduit construction and to reduce the need for taking easements or acquiring properties. Three to five route alternatives were initially identified along each reach of the consolidation conduit. In most cases, any route alternative from an upstream reach could connect to any route alternative in the next downstream reach. Through an evaluation process that compared each route alternative based on engineering, environmental, community, and economic factors, and an extensive public participation program, the number of route alternatives to undergo additional evaluation was reduced. As a result of this evaluation process, three route alternatives were selected for additional evaluation for two of the reaches, and two route alternatives were selected for the third.

A planning-level subsurface exploration program was conducted to obtain necessary information on ground conditions and to define top of rock for the route alternatives undergoing additional evaluation. Soil profiles and rock contours from existing borings and geophysical programs were obtained and reviewed, and additional borings and geophysics were performed. Borings were spaced from 150 to 610 m (500 to 2,000 ft) apart, depending on the availability of existing information. A seismic refraction survey along two of the three reaches of the conduit was performed to determine top of rock in areas where there was concern that rock could rise to the depth of the invert of the soft-ground conduit.

Route alternatives within each conduit reach were compared based on cost and construction risk factors, including soil conditions, groundwater flows, the potential to encounter obstructions, and the potential for soil and groundwater contamination. Environmental impacts were also evaluated and compared. The preferred routes within each reach were combined to create the overall preferred alternative for the North Dorchester Bay consolidation conduit. In general, the selection of preferred routes reflected a balance between cost and construction risk. For the upstream reach of the conduit, the second-lowest-cost route alternative was preferred. The cost for the preferred route alternative was seven percent higher than the low-cost alternative and presented the lowest construction risk of the three alternatives. In the middle reach, cost varied by only five percent among the route alternatives, and the alternative with the lowest construction risk was chosen. For the downstream reach, the higher-cost route alternative was preferred. Even though the preferred alternative had an approximately 15 percent higher cost, the lower-cost route represented an unacceptable construction risk. The lower-cost route would follow a narrow residential street, while the higher-cost, preferred alternative would run through a park. If the TBM were to encounter an obstruction and require recovery by excavation from the surface, the impacts of the excavation on the residential area would be substantially greater than the impacts on the park. Since the potential level of disruption to the residential area was judged to be unacceptable, the higher cost alternative was selected. The overall preferred route for the North Dorchester Bay consolidation conduit was shown in Figure 1.

CSO Facility Treatment and Pumping Technologies

A CSO facility at the downstream end of the North Dorchester Bay consolidation conduit was recommended to provide the necessary treatment, effluent pumping, and dewatering functions for flow conveyed and captured in the consolidation conduit. When the storage capacity of the conduit is exceeded, the facility would provide coarse screening and pump the excess flow to the Reserved Channel. Prior to discharge, flow would be treated by sodium hypochlorite disinfection and sodium bisulfite dechlorination. Flowrates up to the peak which would occur in a typical year would also receive fine screening prior to discharge. At the end of each storm, when interceptor capacity is available, the facility would dewater the consolidation conduit to the local interceptor system.

The CSO facility would consist of an approximately 150-foot diameter circular below-grade structure with five above-grade structures. The following major equipment and features would be included:

- Five 6.6 m^3/sec (150 mgd) wet well / dry well centrifugal effluent pumps installed below grade
- Two 0.44 m^3/sec (10 mgd) wet well / dry well centrifugal dewatering pumps installed below grade
- Two mechanically-cleaned trash racks with 64-mm (2.5-inch) bar spacing installed below grade
- Three mechanically-cleaned fine screens with 6.4-mm (0.25-inch) bar spacing installed in an above-grade building
- Sodium hypochlorite disinfection and sodium bisulfate dechlorination storage and feed equipment housed in an above-grade building
- 22.2 m^3/sec (47,000 cfm) wet scrubber odor control system housed in the same above-grade building as the disinfection and dechlorination equipment
- Above-grade electrical substation
- Personnel spaces, electrical and mechanical equipment, and an area for the removal of coarse screenings housed in an above-grade building

- Above-grade effluent channel around one half of the perimeter of the circular pumping station
- Dual barrel 3,050 mm (10-foot) diameter effluent conduit and subaqueous outfall

Technology evaluations were performed to compare alternative types of effluent pumps, fine screens, and disinfection and dechlorination processes. Alternatives were compared based on capital and O&M costs and non-monetary factors such as effectiveness, operational complexity, and track record for similar prior applications.

In addition to technology evaluations, a total of four alternative CSO facility sites were evaluated and compared. Similar to the process followed to identify alternative routes for the consolidation conduit, the first step in the site selection process was to identify a wide area within which the facility could be located. This area was defined by establishing an optimum location for the facility, based on tunnel route and outfall discharge location, and defining the boundary of the alternative site area based on incremental cost. Moving the facility away from the optimum location would incur additional cost for the consolidation conduit and/or the facility outfall. An increment of 10 percent of the total facility cost was chosen to establish the alternative site area boundary.

A planning-level subsurface exploration program was conducted to obtain necessary information on ground conditions. Site alternatives were compared based on cost, performance, construction risk factors, and environmental impacts. In general, the differences among the sites based on these factors were not pronounced. Cost varied by less than two percent. While the environmental impacts associated with the alternative sites were different, none of the sites was clearly preferred over the others based on environmental impacts. The lowest cost site was determined to offer the greatest performance and the lowest construction risk, and was selected as the preferred CSO facility site.

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE ACTIONS

Based on experience gained on the North Dorchester Bay CSO relocation project, the following conclusions and recommendations are presented:

- CSO relocation should be considered whenever CSO discharges are present in two adjacent or nearby receiving waters, one of which supports critical uses such as swimming or shellfishing while the other does not. The two key factors that made CSO relocation a viable solution for the seven North Dorchester Bay CSOs were proximity of North Dorchester Bay to the Reserved Channel and the bathing and shellfishing uses in North Dorchester Bay as compared to the commercial shipping use of the Reserved Channel.
- In addition to understanding the characteristics and uses of affected receiving waters, it is important to gain an understanding of the configuration and wet weather operating characteristics of the combined sewer system in order to properly size and evaluate CSO control alternatives. A detailed understanding of system hydraulics is necessary to assure that CSOs can be permanently closed by relocating these discharges to another receiving water segment.
- Compared to sewer separation, CSO relocation offers water quality advantages to the receiving water from which CSOs are eliminated. Pollutants in the additional stormwater discharges that result from sewer separation can partially or even completely offset the benefit gained by eliminating CSO. In addition, CSO relocation offers the potential to control existing stormwater discharges in conjunction with relocating the CSOs.

As previously noted, the North Dorchester Bay CSO relocation project is currently under design. Additional subsurface investigations are being performed to develop the consolidation conduit design, and treatment and pumping technologies for the CSO facility are being refined. Additional hydraulic evaluations and modeling are underway to refine the sizing of both the conduit and CSO facility. These steps, along with other aspects of the design process, will lead to the successful implementation of this project to eliminate CSO discharges to North Dorchester Bay.

COST EFFECTIVE CSO REDUCTION: MAXIMIZING WET WEATHER FLOW TO THE POTW

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ABSTRACT

The Environmental Protection Agency's (EPA's) combined sewer overflow (CSO) Control Policy encourages municipalities, as part of their long-term CSO control planning, to maximize treatment of wet weather flow at existing POTWs. EPA points out the benefit of this action includes:

- Minimizes wet weather overflows.
- Ensures that wet weather flows receive primary treatment.

This paper illustrates another important benefit of maximizing wet weather flow to the POTW, its cost effectiveness. This is demonstrated using data from New York City's (NYC's) Inner Harbor CSO Facility Planning Project, which has shown that this control strategy can lead to a 74 to 88% capture of CSO.

NYC's Inner Harbor CSO project area is served by three (3) wastewater treatment plants with a total CSO drainage area of 20,000 acres. The Inner Harbor has 165 CSO locations and a residential population of 1.7 million people.

The Inner Harbor treatment plants have the capacity to treat up to twice their design flow during wet weather. Calculations were performed during CSO facilities planning using a rainfall runoff model to simulate the annual average capture of combined sewage at each of the three POTWs. The analysis indicated that a significant portion (74 to 88%) of the potential CSO could be captured and treated to primary treatment levels maximizing wet weather flows to the treatment plant.

This CSO control strategy has been shown to be the most cost-effective method of addressing CSO in NYC's Inner Harbor since it makes use of existing treatment and conveyance capacities.

INTRODUCTION

In April 1994, the EPA finalized and signed its CSO Control Policy in the Federal Register (EPA, 1994). The Policy set a comprehensive national framework for CSO control planning and provided guidance to municipalities and permitting authorities in their CSO planning. With almost 1,000 communities nationally with CSO systems and a projected cost of over $40 billion to control CSO discharges, the Policy has a significant national impact.

This paper addresses one of the required control strategies in EPA's CSO Policy, maximizing wet weather flow to the treatment plant, and demonstrates its cost-effectiveness based on New York City's Department of Environmental Protection's (NYCDEP) implementation of this strategy. Maximizing wet weather flow is beneficial since it: 1) reduces the magnitude, frequency, and duration of CSO events; and 2) provides the required minimum treatment of CSOs, which includes screening, settling and disinfection.

The EPA's CSO Control Policy requires CSO communities, as part of their planning efforts, to maximize treatment of wet weather flow at the treatment plant. Specifically, both the nine minimum controls section and the long-term control plan section of the Policy require that wet weather flows be maximized to the wastewater treatment plant. The "Guidance Document for Nine Minimum Controls" (EPA, 1995) in its description of this control strategy, calls for an analysis of plant flow capacity on evaluation of treatment performance for both dry and wet weather periods, and states that municipalities should further evaluate this control during the development of the long-term control plan.

In addition to the CSO Policy requirements, POTW discharge permits generally require that the existing plant capacity be maximized during wet weather conditions. This is a requirement of NYC's State Pollution Discharge Elimination System (SPDES) permits for its 13 treatment plants that serve combined sewer areas. In NYC, the treatment plants primary facilities (i.e., screens, primary tanks, and chlorine contact tanks) are designed to treat up to twice their design dry weather flow capacity during wet weather. The use of this treatment capacity is required by the EPA CSO Policy and plant discharge permit.

NYC's Program

The NYCDEP is currently developing and implementing its City-Wide CSO Facility Planning Program. This $1.5 billion program is addressing CSO pollution in New York City. With over 4,800 miles of combined sewers and approximately 400 CSO discharge locations, New York City has the largest and most extensive CSO system in the nation.

To make city-wide CSO planning manageable, the City has been broken down into four area-wide planning areas (see Figure 1). One of the four facility planning areas is the Inner Harbor. The Inner Harbor study area contains a population of approximately 1.7 million people, encompasses over 20,000 acres of land, has approximately 160 CSO locations, and includes the drainage area of three major wastewater treatment plants: North River, Newtown Creek and Red Hook as shown in Table 1.

Table 1

Inner Harbor – Existing Conditions

Treatment Plant	Dry Weather Flow Capacity (mgd)	Wet Weather Flow Capacity (mgd)	Combined Sewer Drainage Area (acres)	No. of CSOs	Population (Thousands)
North River	170	340	5,600	61	560
Newtown Creek	310	700(1)	12,000	78	970
Red Hook	60	120	3,400	28	195

(1) Currently be upgraded from 620 to 700 mgd wet weather capacity

METHODOLOGY

To estimate the CSO volume capture of the Inner Harbor treatment plants, a rainfall-runoff computer model was developed. The model was developed to have the ability to quickly run long-term hourly rainfall records which was found to be time consuming and cumbersome with the SWMM EXTRAN models developed for this project. A one-year hourly rainfall record can be analyzed in minutes with the rainfall-runoff models, as compared to SWMM EXTRAN, which requires several days to perform a similar calculation.

The rainfall-runoff model can be used to calculate CSO capture for a given treatment plant drainage area based on the following input parameters:

- Regulator Drainage Area
- Regulator Dry Weather Flow
- Regulator Hydraulic Capacity

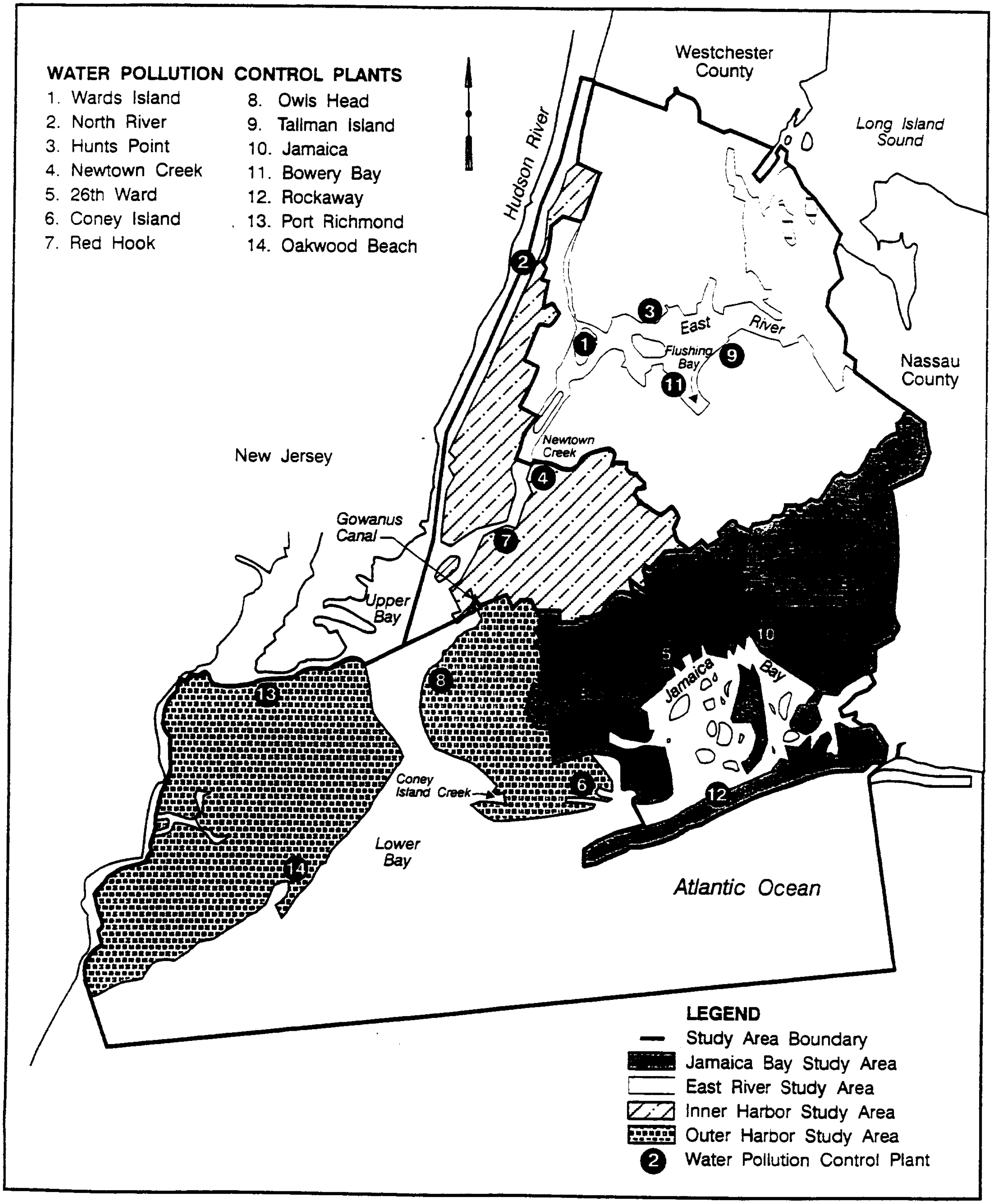


Figure 1 - New York City Areawide CSO Areas

- Regulator Drainage Area Runoff Coefficient
- Treatment Plant Diurnal Flow Pattern
- Treatment Plant Hydraulic Capacity
- Hourly Rainfall

For the three treatment plant drainage areas in the Inner Harbor, the above listed input parameters were collected and developed. The model was executed with over 30 years of historical hourly rainfall from a National Weather Service rain gauge located in Manhattan's Central Park. The results of the model runs are described in the next section.

RESULTS

The results of the rainfall-runoff model runs are presented in Figure 2 and Table 2. Figure 2 graphically presents the resulting total CSO capture from maximizing wet weather flow to the Inner Harbor treatment plants. The hydrographs show that by using the available wet weather treatment capacity (i.e., twice the design dry weather design flow) a significant portion of the potential CSO volume is captured at the plant. CSO capture at the plants ranges between 69 to 83% with an additional 2 to 5% capture due to in-line storage, mainly in the interceptor sewers. The total CSO capture at the plants ranges between 74 to 88% by maximizing the use of existing facilities.

Table 2 summarizes the results of the rainfall-runoff model for the three treatment plant drainage areas. Annual average volumes and percent capture are presented and are based on the 33-year rainfall record.

Table 2

Annual Average CSO Capture

	Annual Average		
Treatment Plant	Wet Weather Captured at Treatment plant (mg)	CSO Volume (mg)	% CSO Capture
North River	8,570	1,220	88
Newtown Creek	15,750	5,430	74
Red Hook	3,220	1,110	74

The volume captures presented have been calculated based on the "Guidance for Long-Term Control Plan" (EPA, 1995) which states that volume capture is based on "the total volume of flow collected in the combined sewer system during precipitation events on a system-wide, annual average basis".

DISCUSSION

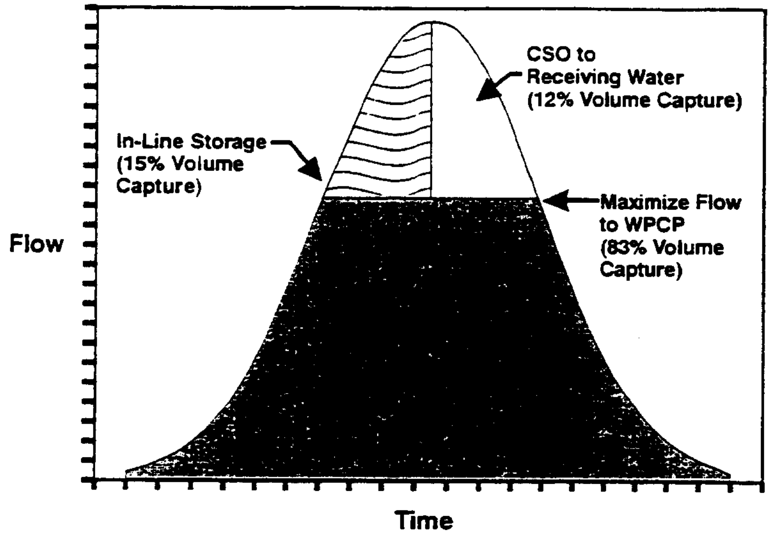
The analysis of wet weather capture at the Inner Harbor plants indicates that a significant portion of the wet weather flow generated can be captured and treated to primary treatment levels. By using the existing regulator, interceptors, and wastewater treatment plant capacities results in a cost-effective method of CSO reduction.

The Inner Harbor long-term CSO facility plan (NYCDEP, 1993) recommended the capture of wet weather flows at the treatment plants to address CSO pollution. It was demonstrated during the facility planning process that Inner Harbor CSOs have a minimal impact on dissolved oxygen and coliform levels in the open waters of the study area. This is due to the fact that the open waters (i.e., Hudson River, East River, and Upper Bay) are large waterbodies with substantially mixing and dilution capabilities. No water quality violations of DO or coliforms in the Inner Harbor are attributable to CSO discharges.

CONCLUSION

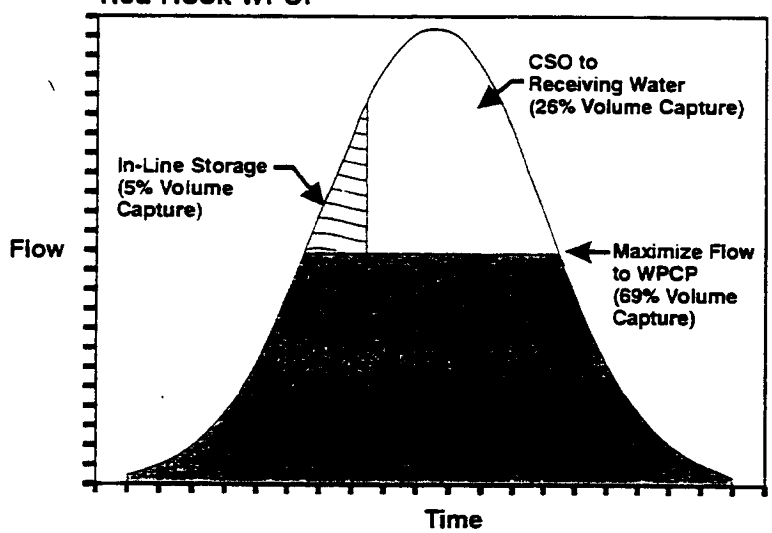
By maximizing wet weather flow and using existing facilities, traditional capital intensive CSO solutions such as off-line storage tanks, tunnels, and swirl concentrators, were avoided resulting in significant cost

North River WPCP



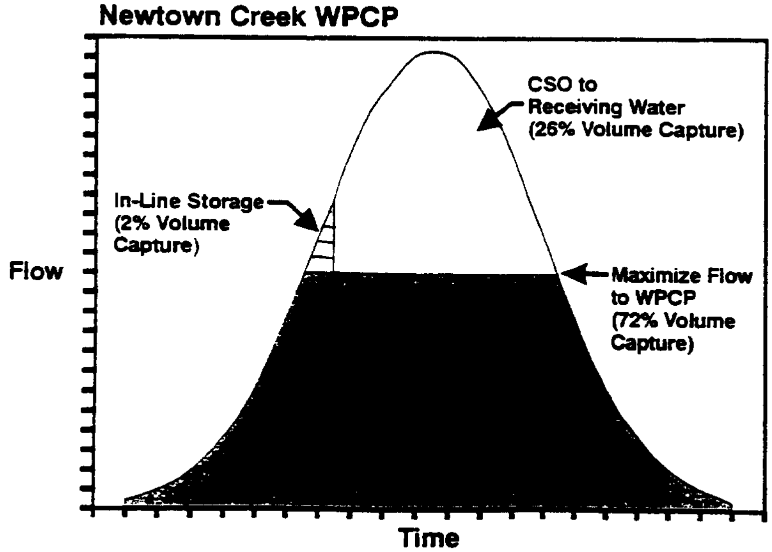
Total CSO
Volume Capture = 88%
(Annual Average)

Red Hook WPCP



Total CSO
Volume Capture = 74%
(Annual Average)

Newtown Creek WPCP



Total CSO
Volume Capture = 74%
(Annual Average)

Figure 2- CSO Volume Capture

savings. EPA's CSO Needs Survey projected a CSO control costs of approximately $630 million for the Inner Harbor area based on area and population. However, the recommended plan, which relies on maximizing wet weather flow to the treatment plant , is estimated to cost $15 million.

Thus, this control strategy is cost-effective and results in a significant reduction in CSO volume.

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IN-LINE STORAGE WITH AND WITHOUT REAL TIME CONTROL

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ABSTRACT

The City of Winnipeg initiated a major Combined Sewer Overflow (CSO) Management study in 1994 to "establish a cost-effective prioritized implementation plan for remedial works based on assessment of costs and benefits of practicable alternatives". Results from phase 3 of the 4-phase study strongly indicate that use of available in-line storage in the 43 individual combined sewer districts (total area about 10,000 ha) is the most effective and logical first step in the emerging wet weather pollution control plan. A "demonstration approach" was used to assess whether or not a proposed control plan could effectively achieve specific water quality objectives. As well, it was deemed important to asses options that were consistent with the EPA "presumptive approach" goals of 4 overflows and 85% capture.

A detailed review of Winnipeg's combined sewer systems confirmed that the volume of available in-line storage was substantial but unevenly distributed. Planning level models were developed to assess the use of existing in-line storage, identify strategic locations for additional storage/district transfers, optimize dewatering and conveyance rates, evaluate wastewater treatment plant limitation/upgrade requirements, and assess receiving stream water quality improvements. Real-time control and non-RTC strategies were evaluated to identify practicable control options which could maximize the use of available in-line storage without increasing the risk of basement flooding. It was found that strategies involving local RTC were less costly and could fully utilize available storage but contained a small element of risk. A non-RTC option involving "finger" weirs was found to be effective, contained no risk, but could not fully utilize storage.

This paper will present the analyses and the description of trade-offs between cost, risk, and performance measures of the range of storage options.

KEYWORDS

combined sewer overflows, in-line storage, real time control

INTRODUCTION

Winnipeg is the capital city of the Province of Manitoba, Canada, and is situated on the confluence of two major rivers, the Red and the Assiniboine rivers. Winnipeg's current population is about 650,000 and comprises a developed area of about 28,000 ha. The older central portion of the City is about 10,000 ha in size, and is serviced by a combined sewer system. The combined sewer serviced area is divided into 43 combined sewer districts, each of which overflow from 7 to 37 times during the recreation season (May to September, inclusive). During dry weather, the flow is diverted into interceptors and brought to three water pollution control centers (WPCCs) for complete secondary treatment. Plans are underway to disinfect the dry weather effluent from one of the treatment plants and the other two plants are under study.

The City is currently working on a combined sewer overflow (CSO) management strategy to develop various plans to control CSOs in the future. The CSO control strategy plan development involved an extensive technology review. This included:

- Best Management Practices (BMP);
- Separation (either full or partial) of the combined system;
- Storage (with and without district transfers)
  - off-line
  - tunnel/transport
  - in-line
- High rate treatment
  - Retention Treatment Basins (RTB)
  - Vortex Solid Separators (VSS)
- Floatables capture.

An integrated modeling approach was used to determine how each of the various candidate options for CSO control would perform. The integrated modeling approach involved three types of models which were sequentially linked:

- an urban hydrology model to estimate the runoff from a wide-variety of rainstorms over the year;

- a sewer system/control alternative model to simulate behaviour of the hydraulic system and thus determine when and where overflows would occur, the volume of interception, the volume of overflow, and the benefits of various control measures; and

- a receiving stream model was used to assess the hydrodynamics and biokinetics of the river water quality, i.e., transport, mixing, fecal coliform die-off, etc., in response to dry and wet weather loadings from the full range of urban discharges.

The various alternatives were assessed in terms of their performance with respect to various performance measures such as number of overflows, volume of overflows and compliance with surface water quality objectives for the receiving streams.

SEWER SYSTEM CHARACTERISTICS

Winnipeg is a very flat prairie city located in the Red River Valley. Generally, the elevation difference throughout the City is about 3 to 4 m (10 to 13 ft.). The Red and Assiniboine rivers water level is only 3 to 4 m below street level along the riverbanks. In addition, the hydrology of the prairie region, which may be relatively dry compared to the East Coast cities, creates large and intensive thunderstorms at least once a year. These geographical factors resulted in the design of existing sewer systems for protection of basement flooding with very flat grades and large diameters.

During dry weather flow, all wastewater is diverted into an interceptor and subsequently conveyed by a gravity to one of three wastewater pollution control centers (WPCC) for full secondary treatment processing before it is discharged to the rivers. However, during wet weather conditions, flow into the system is significantly greater than dry weather flow (DWF) and results in combined sewage overtopping the diversion weir and spilling into the river.

A typical sewer in one of the 43 districts has a 3 m diameter pipe extending 2 to 3 km perpendicular to one of the rivers. During typical operation, the dry weather flow in the combined sewer occupies only a small depth in the bottom of the sewer. A low weir, 0.3 to 0.6 m in height, typically diverts dry weather flow (DWF) either directly into an interceptor or to a pump station where it is delivered to the interceptor. During severe rainstorms, these same sewers are often surcharged, however, significant sewer storage volume is available for more routine rainstorms and could be potentially accessed for use as in-line storage.

The original sewer designs in the city allowed for flood protection of up to a storm of a 1-in-2 year occurrence. Over the past three decades, the City has been upgrading the combined sewer system to allow protection from basement flooding for a storm of up to a 5-year occurrence. These sewer relief programs have often resulted in the addition of a second major sewer pipe in each combined sewer district of comparable size to the main combined sewer trunk (e.g., 3 metres). These relief pipes offers the potential for increasing the volume available for in-line storage in each district.

DEVELOPMENT OF IN-LINE STORAGE ESTIMATES

In-line storage is the latent volume contained within the existing sewer pipe network that can be safely accessed through the use of a control device. Specifically, the control device is intended to cause excessive flows in a the sewer system to be stored in the pipes up to a safe level that does not decrease the existing level of the basement of flood protection. Figure 1 illustrates a typical profile of a combined sewer trunk found in Winnipeg.

Preliminary analysis of Winnipeg's combined sewer system found that large volumes of in-line storage may be available and could significantly reduce the number and volume of CSOs in a cost-effective manner. Accordingly, it was necessary to conduct a detailed review of the combined sewer systems to assemble the data needed on pipe geometry and critical elevations (invert and ground) to improve the accuracy of in-line storage volume calculations for all 43 combined sewer districts in Winnipeg. Once this information was assembled, it was possible to calculate the volume of storage available in each pipe for a specified weir or control elevation.

During the course of the CSO study, the need to investigate the different in-line storage concepts and control technologies evolved. The following three control concepts are the most relevant to the Winnipeg situation.

- Automated gate control
- Fixed finger weirs
- Accessing existing passive / latent storage.

The following discussion elaborates on these three control concepts as they relate to Winnipeg's CSO study and relevant local circumstances.

Real Time Control Gate Option

A review of rainfall history (recent 35 years) was conducted to understand the number and size of rainfall/runoff events that Winnipeg typically experiences during the open water recreation season (May 1 to Sept. 30 inclusive). It was found that most rainfall events are well below the hydraulic capacity of the combined sewer and could be stored within the system. The use of an automated gate system to access available in-line storage by temporarily holding wet weather flows (WWF) within the system during and after small rainfall events is one option under consideration. Runoff from these small rainfall events could be completely stored within the combined sewer system and then dewatered during and after the storm event (see Figure 2b).

The gate control option was assessed to estimate receiving stream impacts. The gate, initially open and in the "home position", would shut during the start of a wet weather event and remain shut until the event was completely over and the sewer was dewatered unless the water level in the sewer rose to a specified critical condition. If the water level or the rate of rise met a predefined trigger condition at selected strategic locations within the sewer system, the gate could be operated in the following two different modes.

- continuous modulation of the automated gate to fully utilized in-system storage while maintaining the existing level of basement flood protection; or
- opening the gate fully and leaving it open to assure that levels in the sewer would not threaten basement flooding.

In the first method, the maintenance of the level in the sewer at an elevation that would not threaten basement flooding would maximize the volume of in-line storage. It requires accurate hydraulic representation of the sewer system under the range of gate operating procedures to achieve this available storage without a threat to basement flooding.

Other operating concerns related to repeated surcharging of the systems presented serious design considerations. There was concern that the modulating method may lead to waterhammer, air surges, weakening of structural integrity, and increased the formation of sinkholes in or along the sewer system due to repeated surcharging.

An alternative gate protocol was developed involving the release of all of the stored combined sewage whenever the water level reached the specified critical elevation. This operation would cause more volume of combined sewage to be released to the river. Since even a small overflow would likely cause a violation of the microbiological water quality objective (i.e., fecal coliforms) designated to protect recreation (either 200 fc/100 mL or 1,000 fc/100 mL), the number of overflow events throughout the recreation season would be the same regardless of the operating protocol used. It should be noted that the automatic gate operation can be accomplished by local, i.e., district-specific RTC, since each district acts as a relatively discrete watershed to the interceptor. The dewatering of the various in-line storage elements in the different districts may require a system-wide or global RTC.

A second consideration used in the development of the gate operation strategy was the selection of the specified target elevation below which the combined sewage could be safely stored without affecting the existing level of basement flood protection. The water level and/or its rate of rise would be closely monitored and used to initiate gate opening to maintain the existing level of service with respect to basement flood protection. A key factor in gate automation is the speed at which it could be opened to permit system hydraulics to react quickly enough to keep pace with changes in a storm intensity and associated runoff and inflows. The gate operation is considered to have a fully automated real-time control system. Selection of these "trigger" conditions would have to be developed using sophisticated computer modeling.

A Workshop involving North American and European experts was held on the operations of in-line storage systems to review and assess its practicability to local conditions. The session identified that, due to the very flat sewer grades found in Winnipeg, there was the potential that air could be trapped in pockets at the top of the sewer and result in a air surges during wet weather operation of the gates. These air pockets could cause air surges to develop in response to the rapid filling of the combined sewer system under close gate conditions and could translate into pressure surges in service connections of homes and businesses at various locations along the sewer system. To prevent this conditioned from forming, it was determined that in-system storage levels should not exceed the obvert elevation of the sewer pipe at the selected location for automated gate control. Due to the relatively flat grades of the sewers, limiting levels to this control elevation would still allow for substantial realization of available in-line storage in each combined sewer district.

A second constraint was placed on the water surface profile to maintaining existing basement flood protection levels. A minimum depth of 3.0 m (approximately 10 ft) below minimum ground level was used as the maximum elevation the water surface profile would be allowed to reach in order to protect against basement flooding under in-line storage conditions, i.e., depths greater than 3.0 m below minimum ground elevation were considered adequate to protect against basement flooding for the current level of service. Accordingly, the minimum elevation of either the obvert or minimum ground elevation less 3.0 m was used as the control elevation to estimate available in-line storage.

One of the primary concerns associated with the use of real-time control for an automated gate to access available in-line storage is the potential increase in basement flood threatening risk . In order to minimize basement-flooding risk associated with gate control to a "virtually fail-safe" condition, additional design factors were considered:

- inlet restriction on catchbasins should be utilized to reduce the rate of inflow into the combined sewer system and result in system flow hydraulics no worse than that generated by a one in five year synthetic design storm;
- the logic of gate control systems (with redundancy) have to be developed to open the gate if there is a malfunction or failure in any of the water level sensing monitors;
- gates would have to be designed to open automatically in case of power failures or interruptions (e.g., an air-accumulator connected to a hydraulic operator or an air-driven motor); and
- utilization of the existing flood pumping stations to initiate emergency dewatering of the combined sewer system if the gate fails to open, (e.g., shaft breakage or mechanical malfunction).

Fixed Weir Option

The control concept described above was considered to be "virtually fail-safe". Given a history of basement flooding, there was still concern about added risk of basement flooding to the citizens of Winnipeg under extreme contingencies. Accordingly, other alternatives, which were inherently fail-safe, were considered. A fixed weir utilizing long weir lengths to minimize flow depth over the weir was considered both fail-safe and practicable (see Figure 2c). This option requires the construction of a large weir chamber utilizing finger weirs in the sewer system to achieve the lengths of weir needed (60 m in some cases) to access available in-line storage. The weir chamber would be 13 metres wide, and fit within the roadway right-of-way. A design condition of 150 mm (6 inches) depth of flow over the weir to safely pass a 1-in-5 year design storm was selected. The existing hydraulic gradeline (HGL) for each sewer system under the design event was reviewed to establish the top elevation of the weir (i.e. each HGL-0.15 m).

To maintaining existing basement flood protection levels under this option, a minimum depth of 3.2 m (approximately 10.5 ft) below minimum ground level was used to protect against basement flooding. Accordingly, the minimum elevation of either (HGL less 0.15 m or minimum ground less 3.2 m) was used as the control elevation to calculate available in-line storage.

A fixed finger-weir system to utilize available in-line storage has the advantage of little need for operational attention relative to an automated gate control system and is inherently more fail-safe. However, it is more costly to construct and will only utilize about 80% of the in-line storage that could be achieved through the use of an automated gate control system.

Passive and Latent Storage

Many of the underground combined sewer districts have relief sewers to reduce basement flooding. The primary purpose of the relief systems in Winnipeg is to improve the hydraulic conveyance of wet weather flows (WWF)so as to protect basements from flooding for a given design level of service (e.g. 1-in-5 year return frequency storm). The relief systems are designed to be active (i.e., overflow to the rivers) only during rainfall conditions. As described earlier, a low-level weir was historically installed in the combined sewer trunk and used to redirect DWF through an off-take system to the interceptor system. The diversion structures were originally designed to divert about 2.75 times DWF. To avoid dry weather overflows from occurring in the relief systems, careful attention was placed on the hydraulic modeling and design of relief overflow activation levels. Specifically, hydraulics in both systems (combined sewers and relief piping) were synchronized such that overflow from the relief system did not occur prior to overflows from the combined sewer system. The storage of combined sewage contained in the combined sewer system up to this activation level represents existing passive in-line storage volume.

Currently, many of the relief sewer pipes that are part of the combined sewer systems are below normal river water level (see Figure 2d). Each relief system outfall has a flap-gate installed to prevent river water from entering the sewer system. The majority of these relief pipes do not have a dewatering system and remain partially full under normal river water level conditions. As such, the combined sewage will remain in the relief pipe between storms until it is displaced by flows resulting from the next rainfall event. If this combined sewage could be dewatered to the interceptor, a significant amount of storage would be available to store small storms, and accordingly is considered latent storage.

COMPARISON OF IN-LINE STORAGE AVAILABLE

In-line storage calculations were performed for each of the 43 combined sewer districts to quantify the potential volume of storage available for each of the 3 control concepts previously discussed (i.e., gate, weir, and latent storage). The results are summarized on Figure 3. The automated gate option allows for the greatest volume of storage to be utilized, about 360,000 m^3. The fixed-weir option achieves about 300,000 m^3 of storage. Accessing existing passive and latent storage would provide in the order of 130,000 m^3 of storage. The cost of the automated-gate option is about $ 50 Million compared to the higher cost for the fixed weir of $ 100 Million. The risk of failure associated with the automated-gate option must be considered and the economic penalty of failure accounted for in the decision-making process. In order to safely access in-line storage, (i.e., reassure the public that there is no increase in the risk to basement flooding), the fixed weir option may be the only option the public will support. Existing latent storage could be accessed now but would require dewatering facilities to be installed and ensuring flap gates are operating correctly. This cost associated with accessing latent storage would be significantly lower than either of the other two options.

INTEGRATION WITH FUTURE BASEMENT RELIEF PROJECTS

The City of Winnipeg has an ongoing program to improve basement flood protection on a prioritized basis. The most flood-prone combined sewer districts are ranked and given highest priority for installation of relief sewers. Figure 4 shows the combined sewer districts that have been relieved and the remaining districts that require some degree of relief to improve basement flood protection. An estimate of potential increase in the in-line storage that could result from new relief pipes, for each of the in-line storage control concepts considered is shown on Figure 3. The analysis indicates that latent storage could be significant if it were possible to install all new relief pipes at a depth that the normal river level would control (i.e., below river level and held back by flap-gates). Specifically, future relief projects could potentially achieve as much in-line storage as the existing system with an automated gate control scheme, although the distribution of the storage in the system may not be optimal. New relief projects represents a very important opportunity with respect to supplemental in-line storage volumes that could significantly reduce the need for more expensive and complicated control technologies. Clearly, the addition of new relief pipes can provide improved basement flood protection while reducing the number and volume of CSO. The need for CSO control provides the opportunity to expand the design criteria of proposed relief projects to include consideration of cost-effectively maximizing in-line storage and minimize wet weather impacts.

CONCLUSION

In-line storage can be a cost-effective method of reducing combined sewer overflows. The use of automated gate controls is one method of maximizing the use of the available in-line storage at a reasonable cost. Concerns from the public that this automated system may increase the risk of basement flooding under worst-case contingency events, even if the risk is very low, may preempt its use. Alternative methods such as use of fixed weirs and using latent storage may access significant in-line storage for CSO control

Designing future basement relief projects with due consideration for increasing latent storage may prove to be a very effective integrated long term CSO control solution.

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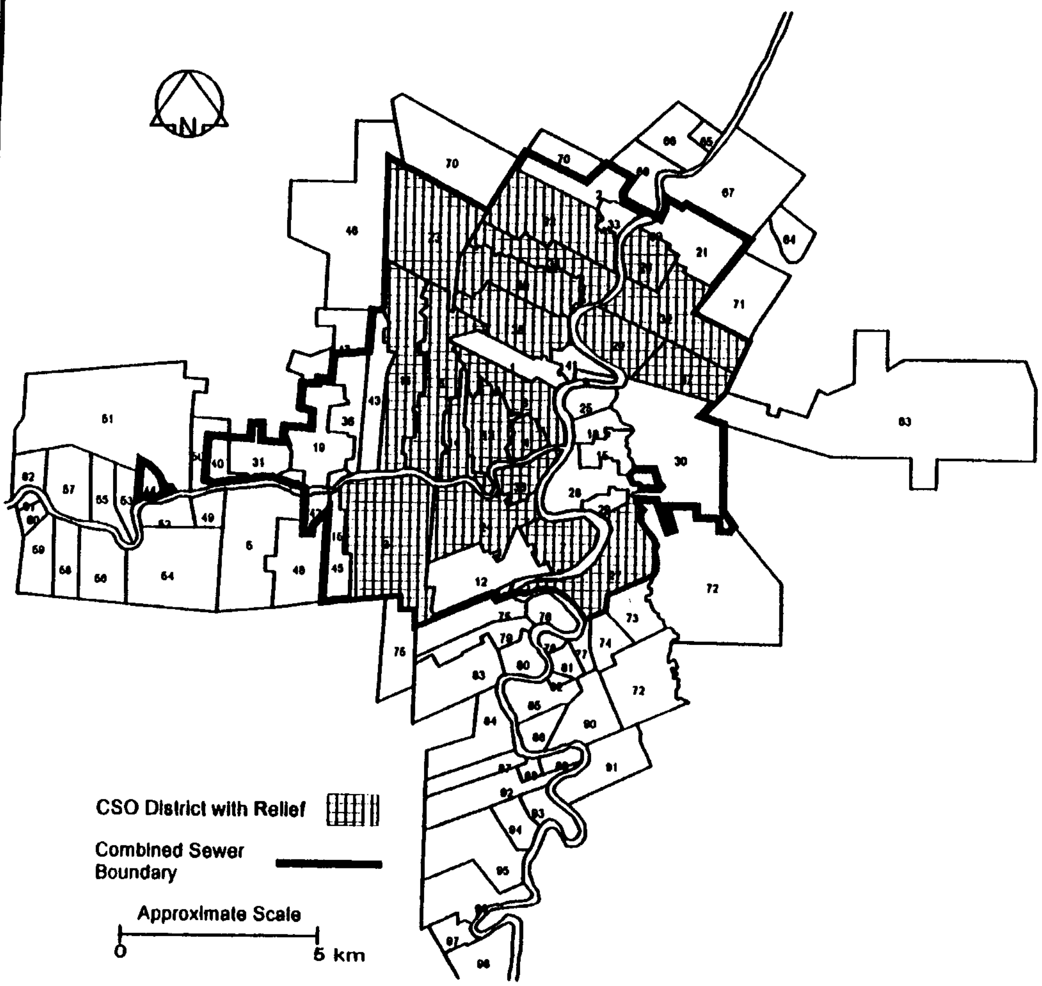


CSO Districts with Sewer Relief

Figure 4

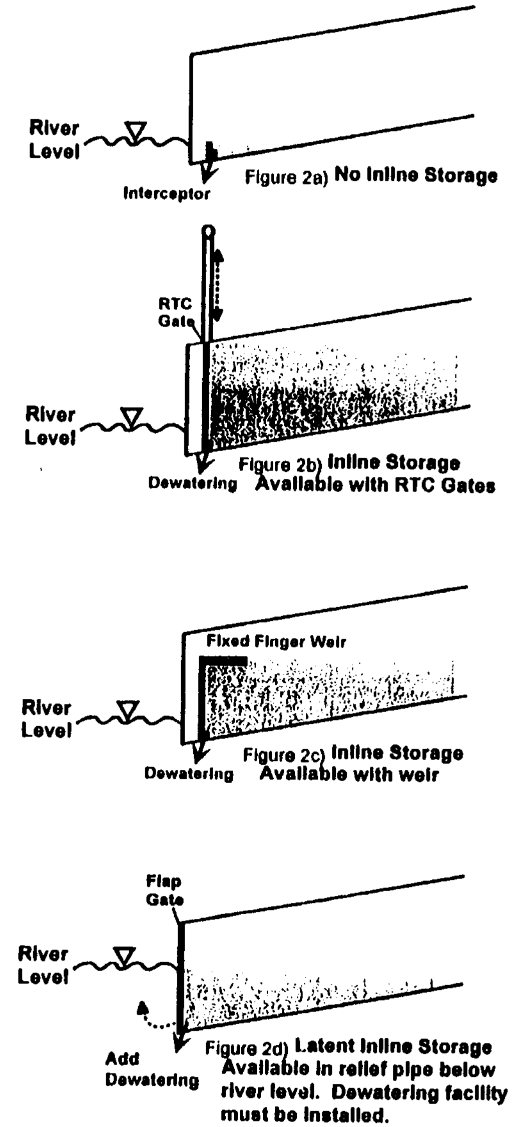


Figure 1: Illustration of Potential In-line Storage in an Actual CS Trunk

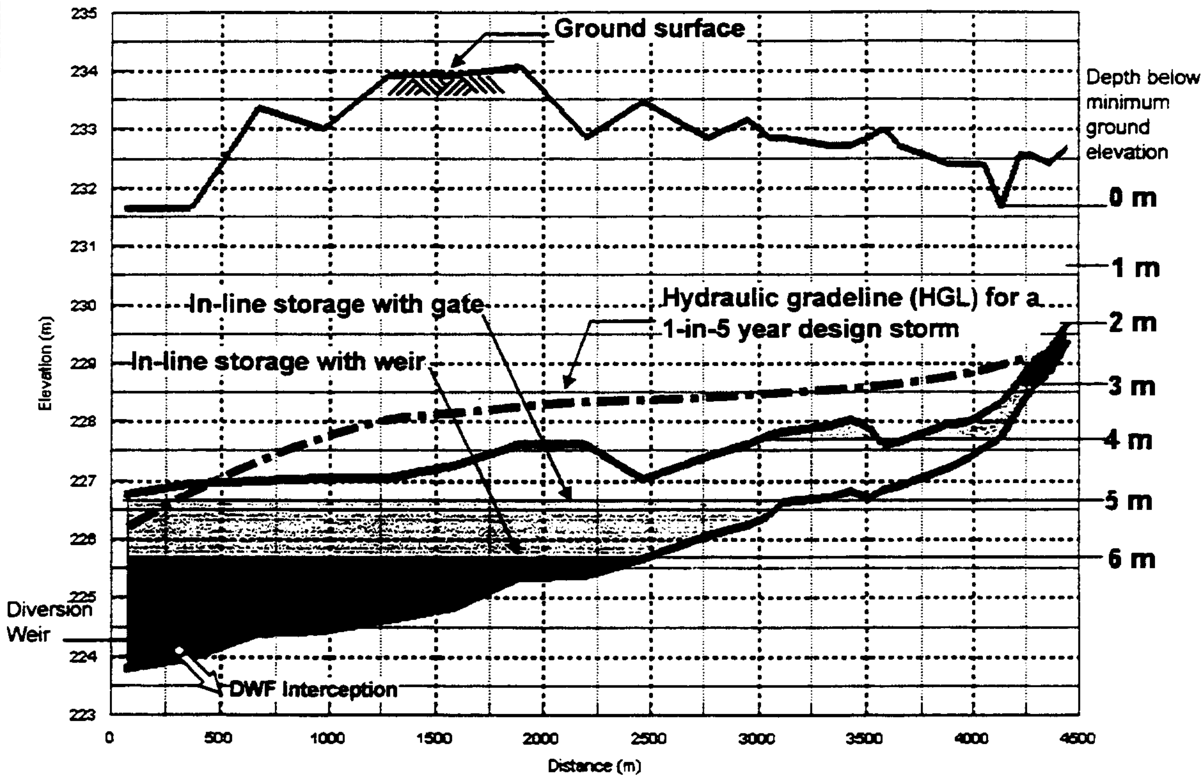
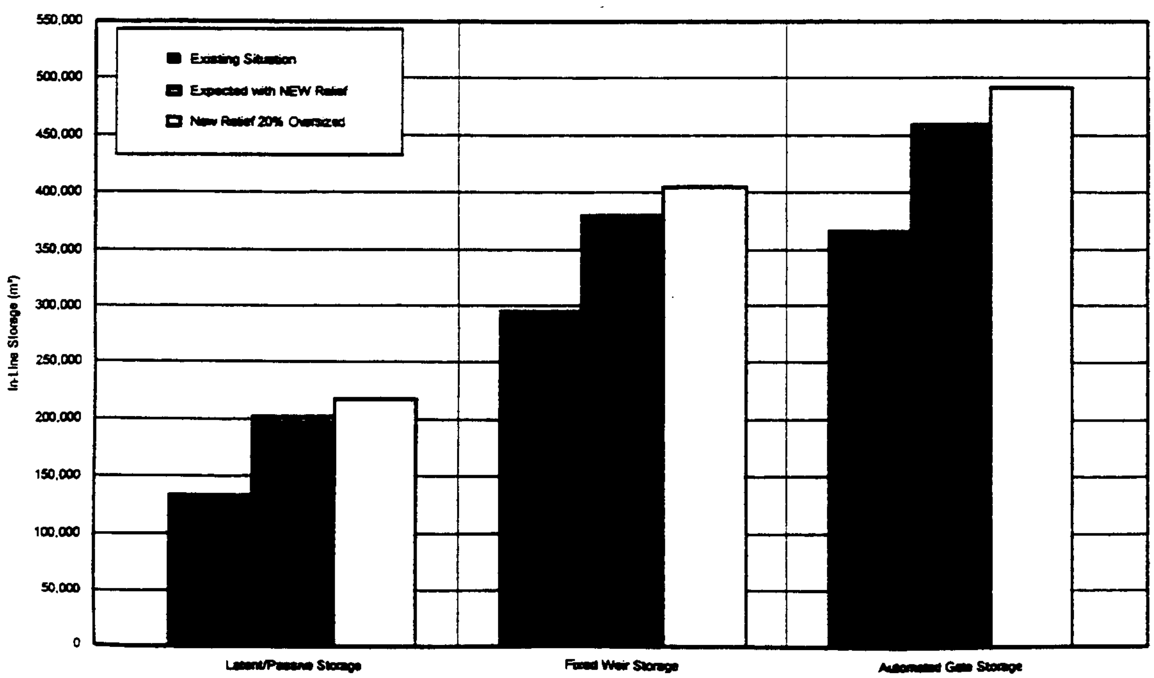


Figure 3: In-Line Storage Potential • Additional Volume Range

Extrapolation based on Existing CS Districts with Relief



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ASSESSMENT OF THE EFFECTIVENESS OF A WET WEATHER STORAGE/TREATMENT FACILITY

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ABSTRACT

Performance data and treatment effectiveness at a CSO treatment facility are presented and discussed. During the spring and summer of 1997, extensive flow monitoring and sampling of the influent and effluent of the facility was conducted. Six storm events of various rainfall depths and duration were monitored for influent and effluent activity. Data were analyzed to assess pollutant load removal effectiveness for various parameters, including biochemical oxygen demand (BOD), suspended solids, bacteria, ammonia, and seven metals.

KEYWORDS

combined sewer overflow, treatment effectiveness, wet weather flow, combined sewer overflow storage

INTRODUCTION

A study was undertaken as part of the Westerly CSO Phase II Facilities Plan to evaluate the treatment effectiveness of the Northeast Ohio Regional Sewer District's (District) Westerly Combined Sewer Overflow Treatment Facility (CSOTF). Flows and pollutant loads were measured and the level of treatment determined for the varying storm events evaluated.

The District owns and operates three wastewater treatment plants (WWTP) that serve the Greater Cleveland area: Westerly, Easterly and Southerly. The Westerly District consists of approximately 40.47 km^2 (10,000 acres) on the west side of the City of Cleveland, 75 percent of which are served by combined sewers. Four interceptors—Westerly, Walworth Run, Northwest and Low Level—convey flows to the treatment plant. The Westerly WWTP is currently designed for 1.5 m^3/s (35 mgd) of dry weather flow. Wet weather flows up to 3.1 m^3/s (75 mgd) currently receive full treatment. Additional improvements planned at the plant will increase future wet weather capacity to 4.38 m^3/s (100 mgd). Flows above 3.1 m^3/s (75 mgd) are currently directed to the CSOTF.

The CSOTF was constructed for storage and treatment of combined sewer overflows collected from various locations across the service area. The Northwest Interceptor (NWI) functions with CSOTF to collect combined sewer overflows from the Lake Erie beach areas and Rocky River area and convey them to the CSOTF for storage and treatment.

Description of Facility and Operation

The facility is designed to provide storage for up to 47 300 m^3 (12.5 MG), sedimentation for up to 13.1 m^3/s (300 mgd), coarse screening for up to 39.4 m^3/s (720 mgd), and to hydraulically convey a peak flow rate of 78.9 m^3/s (1,800 mgd). Gates at the northerly end of the CSOTF influent channel open when flow rates exceed 13.1 m^3/s (300 mgd) and excess flow is transported to Lake Erie.

Flow to the CSOTF is controlled by a combination of static and automated regulators in the upstream interceptor system. During wet weather, excess flows from combined sewers and the Westerly Interceptor are routed to the NWI. A sluice gate diverts the Westerly Interceptor flow from the treatment plant to the NWI during high water level conditions at the Westerly weir diversion structure. All flow entering the 6.1 m by 2.74 m (20 ft x 9 ft) rectangular NWI is sent directly to CSOTF. The NWI operates only during overflow conditions. The control strategy during overflow conditions preferentially accepts flow from Walworth Run at the WWTP while diverting the Westerly Interceptor flow to the NWI and CSOTF.

Figure 1 is a site layout of CSOTF. Overflow from the Westerly system passes through 50.8-mm (2-inch) openings in two coarse bar screens into a 6.1 m x 6.71 m (20 ft x 22 ft) concrete center channel. The center channel is lined with 16 sluice gates which control the flow into four quadrants (quads). Each 30.78 m (101 ft) wide by 33.53 m (110 ft) long quad is comprised of four bays. At the entrance to each bay is a 1.22 m by 1.22 m (3 ft x 3 ft) sluice gate. Just past the gates is a 1.68 m (5.5 ft) pocket to collect the settled solids. As the water level climbs above 5.73 m (18.8 ft), a settled overflow begins and wastewater discharges over the weir opposite the sluice gate. The settled flow is collected in an open effluent channel and is directed through the outfall conduit to Lake Erie.

Bypassing the CSOTF is accomplished through the center channel using three downward operating sluice gates at the downstream end of the center channel. The 2.13 m x 3.05 m (7 ft x 10 ft) center gate and the two 3.05 m x 3.05 m (10 ft x 10 ft) outer gates are 2.9 m (9.5 ft) above the center channel floor. The gates are operated independently of each other based on water surface levels in the quads and the center channel. Operation of the various bypass gates is controlled by level rise rates in the center channel. When flow to the quads exceeds 13.1 m^3/s (300 mgd), the sluice gates are opened to allow discharge directly to the outfall. If flow entering CSOTF exceeds the bar screens' capacity, the bar screen bypass gates are opened and the sluice gates to the CSOTF quadrants are closed. All flow then bypasses treatment and travels through the center channel.

The storage volume in the CSOTF is about 22 710 m^3 (6 MG). The NWI provides an estimated 22 710 m^3 (6 MG) of additional storage. Storage of 1892 m^3 (0.5 MG) is also estimated to be available in the downstream portions of Walworth Run and Westerly Interceptors. Mass balancing using the flow monitoring data agreed with this estimates. After high flows subside, the stored volume is pumped back to the Westerly WWTP for full treatment.

After an overflow event ends and influent flows to Westerly WWTP decrease, the return flow volume and settled solids are pumped to the headworks for full treatment. High-rate dewatering pumps, capable of flow rates up to 0.11 m^3/s (18,000 gpm), deliver the return flow to the screen building. Sludge pumps remove the solids and discharge them upstream of either the screen building or the aerated grit tanks.

Recent improvements at Westerly WWTP allow Quad B of CSOTF to be used for primary treatment during short-term maintenance at the headworks and primary clarifiers. During these conditions, influent flow is directed to the CSOTF for primary treatment and is returned to the Westerly WWTP for secondary treatment. The return pipe from CSOTF to the plant has a hydraulic capacity of about 1.3 m^3/s (30 mgd).

METHODOLOGY

CSOTF operations were evaluated based on flow monitoring and water quality sampling results from six rainfall events, each of which resulted in overflows at CSOTF. The flow monitoring and sampling effort to collect data for the CSOTF effectiveness evaluation is described in this section. Water quality sampling results and their use in evaluating pollutant removal effectiveness are presented later in this paper.

Flow Monitoring and Water Quality Sampling Program Description

CSOTF effectiveness was assessed based on monitored flows and water quality samples collected at selected locations on both the influent and effluent sides of the facility. These locations are identified on Figure 2. System-wide flow monitoring in the Westerly WWTP district began in mid-March and extended through mid-June, 1997. Eleven flow monitors—three at CSOTF, two at the Westerly WWTP influent and the six most downstream interceptor monitors—remained in service until mid-August.

Influent water quality sampling occurred at a concrete access chamber, located on the line entering CSOTF (Location 1). Each influent sample consisted of three grab samples collected from three different depths within the channel and composited to account for possible vertical variability in influent quality.

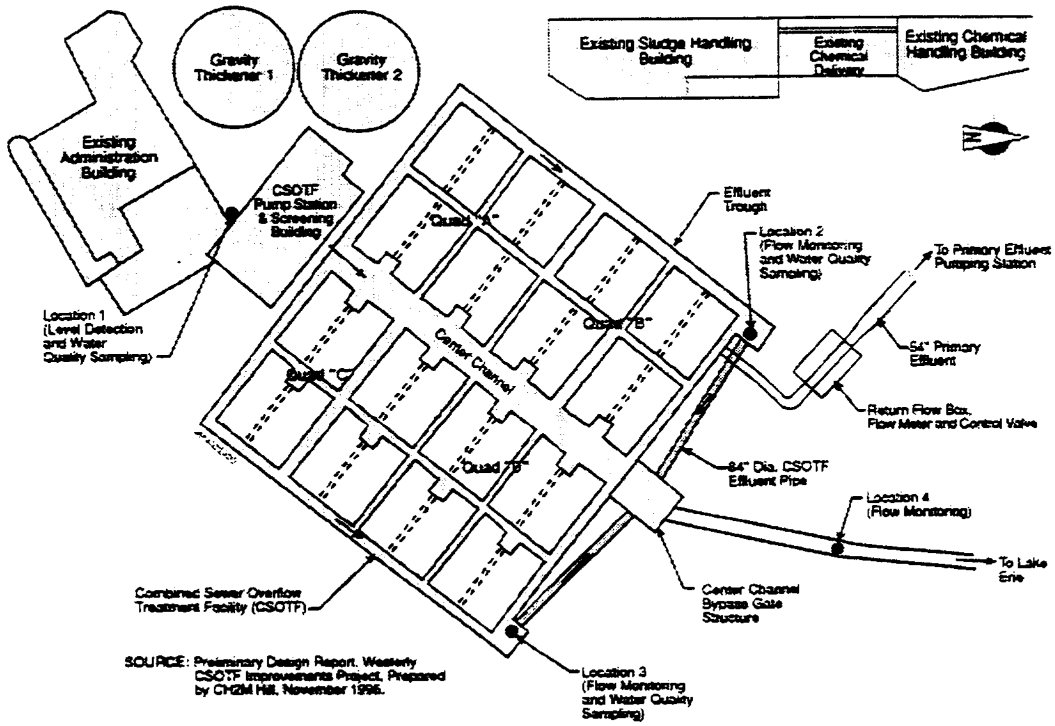
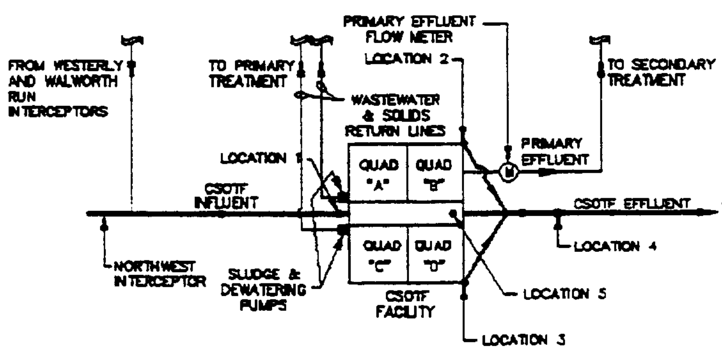


Figure 1. CSOTF Site Plan



LOCATION	LEVEL DETECTION	FLOW MONITORING	WATER QUALITY SAMPLING
1			X
2		X	X
3		X	X
4		X	
5	X		

Figure 2. CSOTF Operation Schematic

Surcharging of the line, combined with restricted space, prohibited the installation of a flow meter. Therefore, the influent flows into CSOTF are based on the effluent flow meters.

Effluent sampling and flow monitoring occurred in the two settled wastewater discharge channels exiting CSOTF (Locations 2 and 3). Flow meters were installed in each of these two channels. Locations 2 and 3 were also equipped with automatic samplers which were operated manually to retrieve samples at one-hour intervals during overflow events.

Three groups of depth sensor gauges were placed in the center channel near the bypass gates. The depth readings were used to estimate the volume of flow through the center channel bypass gates during a CSOTF overflow. Water quality samples are routinely taken at this location and from the Quadrant B settled overflow by WWTP personnel for compliance reporting. Results from suspended solids and BOD tests of these samples were used in this evaluation.

Water Quality Sampling Parameters

Samples were collected and tested in the laboratory for the following parameters: Total suspended solids (TSS), BOD, COD, ammonia, hardness, oil & grease, *E. coli*, fecal coliform and metals (Cd, Cr, Cu, Pb, Hg, Ni, Zn, Fe). Field analysis of the samples included pH, DO, temperature and conductivity. All parameters were analyzed on the first storm event. Based on the sampling results that tested below detection limits, the decision was made to eliminate cadmium, lead, nickel and oil & grease parameters from analysis for subsequent events.

Overflow Events Monitored

Overall, six events were sampled for the CSOTF evaluation. A summary of these events, based on the rain gauge located at the WWTP, is provided in Table 1.

Table 1. CSOTF Evaluation Events

Date	Rainfall			Peak 15-min. Influent Flow		Days Since Facility Last Used
	Depth		Duration			
	(mm)	(in)	(hr)	mm/hr	in/hr	
4/12/97	24.38	0.96	7.5	7.11	0.28	0*
5/19/97	11.94	0.47	0.25	28.44	1.12	4
5/25/97	18.03	0.71	10.83	5.08	0.20	4
5/31/97	19.81	0.78	12.0	6.09	0.24	4
6/2/97	22.61	0.89	4.75	16.25	0.64	0
8/13/97	10.16	0.40	4.0	9.14	0.36	0

* *CSOTF used for Westerly WWTP primary settling*

RESULTS

The results of the monitoring and sampling programs were used in the calculation of removal efficiencies. Tables 2 and 3 present CSOTF removal efficiency for TSS, BOD, chromium, copper, iron and zinc for each of the sampling events. All April 12th field data for the listed parameters and the associated flows is shown in Tables 4 and 5, as an example of the data analysis used to calculate removal efficiencies. Ammonia removals were negligible for all events monitored.

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Table 2. CSOTF Removal Efficiencies for TSS, BOD and Metals during 6 Sampled Events (Metric)

	Comment	Sample Site	Peak Flow Rate (m^3/s)	Incremental Volume (m^3)	Peak CSOTF Loading ($m^3/day/m^2$)	TSS (kg)	BOD (kg)	Chrom (kg)	Copper (kg)	Iron (kg)	Zinc (kg)
Event 1	CSOTF Influent	1	12.4	129 409.2		22 340.1	6 315.6	8.1	13.8	737.8	57.8
4/12/97	CSOTF Quads C&D Effluent	2	5.4	55 261.0	226.6	7 145.1	3 109.8	1.9	2.9	209.9	14.8
	CSOTF Quads A&B Effluent	3	7.0	74 148.2	291.2	7 040.8	2 049.0	1.8	3.3	220.8	16.0
	Removal Efficiencies					36%	18%	55%	55%	42%	47%
Event 2	CSOTF Influent	1	13.0	33 989.3		22 108.9	2 654.9	1.0	2.3	204.9	10.1
5/19/97	CSOTF Quads C&D Effluent	2	6.2	15 821.3	261.3	2 112.9	377.8	0.3	0.7	67.9	3.2
	CSOTF Quads A&B Effluent	3	6.7	18 168.0	282.4	2 723.4	415.9	0.4	1.0	88.9	4.1
	Removal Efficiencies					78%	70%	35%	30%	23%	28%
Event 3	CSOTF Influent	1	6.8	49 015.8		2 052.2	2 101.6	1.3	1.1	55.0	12.7
5/25/97	CSOTF Quads C&D Effluent	2	3.1	22 104.4	129.2	968.7	282.1	0.8	0.3	15.1	8.9
	CSOTF Quads A&B Effluent	3	3.7	26 911.4	153.9	1 036.3	200.5	1.0	0.5	28.8	10.3
	Removal Efficiencies					2%	35%	-49%	24%	16%	51%
Event 4	CSOTF Influent	1	10.3	124 072.3		6 853.5	2 315.6	3.2	1.1	156.8	14.3
5/31/97	CSOTF Quads C&D Effluent	2	4.6	56 018.0	192.5	3 141.0	804.5	2.5	1.5	120.5	9.1
	CSOTF Quads A&B Effluent	3	5.7	68 054.3	236.8	3 222.2	506.1	1.9	1.8	96.0	9.3
	Removal Efficiencies					7%	43%	-40%	-206%	-38%	-29%
Event 5	CSOTF Influent	1	13.2	218 545.9		17 615.4	2 403.2	7.7	8.2	410.9	56.3
6/1/97	CSOTF Quads C&D Effluent	2	6.9	104 049.7	288.4	7 393.7	946.5	1.3	2.7	128.5	19.6
	CSOTF Quads A&B Effluent	3	7.5	114 496.3	312.9	9 371.9	1 002.3	2.3	3.1	155.1	20.5
	Removal Efficiencies					5%	19%	54%	39%	31%	29%
Event 6	CSOTF Influent	1	2.0	5 526.1		0.3	0.2	0.2	*	7.5	1.0
8/13/97	CSOTF Quads C&D Effluent	2	1.0	2 384.6	42.5	0.2	0.3	0.2	*	5.7	0.7
	CSOTF Quads A&B Effluent	3	1.0	3 141.6	44.8	0.1	0.1	0.1	*	2.8	0.4
	Removal Efficiencies					10%	-182%	-76%	*	-13%	-4%

* All values below detection limit.

Table 3. CSOTF Removal Efficiencies for TSS, BOD and Metals during 6 Sampled Events (U.S. Customary)

	Comment	Sample Site	Peak Flow Rate (mgd)	Incremental Volume (MG)	Peak CSOTF Loading (gpd/sf)	TSS (lb)	BOD (lb)	Chrom (lb)	Copper (lb)	Iron (lb)	Zinc (lb)
Event 1	CSOTF Influent	1	282.36	34.19		49,260	13,926	17.87	30.38	1,625.12	127.28
4/12/97	CSOTF Quads C&D Effluent	2	123.55	14.6	5,560	15,755	6,857	4.23	6.45	462.42	32.69
	CSOTF Quads A&B Effluent	3	158.81	19.59	7,147	15,525	4,518	3.89	7.33	486.41	35.18
	Removal Efficiencies					36%	18%	55%	55%	42%	47%
Event 2	CSOTF Influent	1	296.49	8.98		48,750	5,854	2.2	5.13	451.41	22.28
5/19/97	CSOTF Quads C&D Effluent	2	142.47	4.18	6,412	4,659	833	0.61	1.44	149.61	7.03
	CSOTF Quads A&B Effluent	3	154.02	4.8	6,931	6,005	917	0.82	2.13	195.85	8.97
	Removal Efficiencies					78%	70%	35%	30%	23%	28%
Event 3	CSOTF Influent	1	154.36	12.95		4,525	4,634	2.76	2.42	121.15	27.99
5/25/97	CSOTF Quads C&D Effluent	2	70.43	5.84	3,170	2,136	622	1.82	0.71	33.34	19.61
	CSOTF Quads A&B Effluent	3	83.93	7.11	3,777	2,285	442	2.3	1.1	63.5	22.7
	Removal Efficiencies					2%	35%	-49%	24%	16%	51%
Event 4	CSOTF Influent	1	234.06	32.78		15,112	5,106	6.95	2.41	345.32	31.48
5/31/97	CSOTF Quads C&D Effluent	2	104.95	14.8	4,723	6,926	1,774	5.44	3.41	265.38	20.15
	CSOTF Quads A&B Effluent	3	129.11	17.98	5,810	7,105	1,116	4.28	3.97	211.38	20.49
	Removal Efficiencies					7%	43%	-40%	-206%	-38%	29%
Event 5	CSOTF Influent	1	300.73	57.74		38,842	5,299	17.01	17.98	905.09	124.04
6/1/97	CSOTF Quads C&D Effluent	2	157.26	27.49	7,077	16,303	2,087	2.89	5.84	282.95	43.07
	CSOTF Quads A&B Effluent	3	170.62	30.25	7,679	20,665	2,210	5	6.81	341.71	45.16
	Removal Efficiencies					5%	19%	54%	39%	31%	29%
Event 6	CSOTF Influent	1	45.73	1.46		1	0	0.36	*	16.53	2.19
8/13/97	CSOTF Quads C&D Effluent	2	23.15	0.63	1,042	0	1	0.36	*	12.5	1.46
	CSOTF Quads A&B Effluent	3	22.58	0.83	1,100	0	0	0.28	*	6.2	0.81
	Removal Efficiencies					10%	-182%	-76%	*	-13%	-4%

* All values below detection limit

Table 4. April 12 Water Quality Field Sampling Results (Metric)

Storm Event #: 1 Average Rainfall 27.94 mm 4/12/97 Unsettled overflow from the CSOTF occurred from 11:17am to 12:49pm.
Average Duration 9 hours 20 minutes Settled overflow from the CSOTF occurred from 9:15am to 5:10pm

Comment	Site	Time	Flow Rate	Incremental Flow	CSOTF Loading	pH	Temp	TSS		BOD		Chromium		Copper		Iron		Zinc	
			m^3/s	m^3	$m^3/s/m^2$		Deg C.	(mg/l)	kg	(mg/l)	kg	(µg/l)	kg	(µg/l)	kg	(µg/l)	kg	(µg/l)	kg
CSOTF Influent																			
Begin of rain		3:40 AM																	
Begin filling CSOTF																			
Begin of overflow		9:00 AM																	
Initial peak flow		9:45 AM	7.05	0.01															
Sample #1	#1	10:15 AM	5.41	0.01		7.61	7.5	98	2 466	32.6	820	20	0.50	67	1.69	1 910	48.05	303	7.62
Peak CSOTF overflow		**11:15 AM**	12.37	0.02				**69**	1 690	**26.0**	637								
Sample #2	#1	11:45 AM	8.71	0.02		7.77	11.0	628	11 119	208.0	3 683	147	6.20	223	9.41	12 200	514.88	896	37.81
Sample #3	#1	12:30 PM	8.60	0.02		7.84	12.3	160	3 969	18.9	469	24	0.60	60	1.49	3 500	86.82	215	5.33
Sample #4	#1	1:30 PM	4.86	0.03		7.91	11.4	98	2 487	20.0	507	26	0.66	37	0.94	2 800	71.05	206	5.23
Sample #5	#1	2:20 PM	2.17	0.01		7.91	11.8	50	382	15.8	121	12	0.09	24	0.18	1 390	10.61	154	1.18
Sample #6	#1	3:30 PM	0.18	0.00		8.04	12.6	64	245	21.8	84	16	0.06	22	0.08	1 630	6.25	156	0.60
Sample #7	#1	4:15 PM	0.00	0.00		8.05	12.6	70	6	21.8	2	<10		28	0.00	1 540	0.13	159	0.01
End CSOTF overflow		5:30 PM	0.00	0.00															
Total				0.13					22 364		6 322		8.12		13.79		737.80		57.79
CSOTF Quads C&D Effluent																			
Begin of overflow		9:00 AM																	
WWTP Sample		**9:15 AM**	1.44	0.00	**49**			**76**	99	**31.0**	40								
Initial peak/Sample #1	#2	9:45 AM	2.90	0.00	**98**	7.79	9.7	84	383	252.0	1 149	21	0	34	0.20	2 500	14.65	202	1.18
Sample #2	#2	11:00 AM	3.29	0.01	**111**	7.80	10.2	72	739	35.4	363	19	0	32	0.33	2 500	25.66	181	1.86
Peak CSOTF overflow		11:15 AM	5.41	0.00	**183**														
Sample #3	#2	12:00 PM	3.84	0.01	**130**	7.76	9.9	218	3 471	69.5	1 106	67	1	85	1.35	5 600	89.15	425	6.77
Sample #4	#2	1:00 PM	3.57	0.01	**121**	7.67	12.5	142	1 973	22.9	316	28	0	57	0.79	4 600	63.92	255	3.54
Sample #5	#2	2:00 PM	1.15	0.01	**39**	7.90	12.0	56	383	13.4	92	17	0	30	0.21	1 820	12.44	164	1.12
Sample #6	#2	3:00 PM	0.39	0.00	**13**	8.08	12.5	44	95	18.4	40	14	0	22	0.05	1 760	3.78	135	0.29
Sample #7	#2	4:00 PM	0.00	0.00	**0**	8.00	12.9	50	11	19.1	4	<10		20	0.00	1 540	0.33	183	0.04
End CSOTF overflow		5:30 PM	0.00	0.00	**0**														
Total				0.06	743				7 153		3 113		1.92		2.93		209.94		14.80
CSOTF Quads A&B Effluent																			
Begin of overflow		9:00 AM																	
WWTP Sample		**9:15 AM**	2.07	0.00	**70**			**76**	142	**31.0**	58								
Initial peak/Sample #1	#3	10:00 AM	3.85	0.01	**130**	7.79	7.4	70	702	30.3	304	22	0	35	0.42	2 170	25.82	212	2.52
Sample #2	#3	11:00 AM	4.32	0.01	**146**	7.93	9.3	66	693	35.1	368	16	0	36	0.38	2 140	22.47	183	1.92
Peak CSOTF overflow		11:15 AM	6.96	0.01	**235**														
Sample #3	#3	12:10 PM	4.88	0.01	**165**	7.65	10.8	130	2,701	37.2	773	36	1	56	1.16	3 900	81.02	283	5.88
Sample #4	#3	1:00 PM	4.48	0.02	**151**	7.93	11.4	110	1,976	18.0	323	22	0	46	0.83	3 700	66.45	200	3.59
Sample #5	#3	2:00 PM	1.56	0.01	**53**	7.94	12.4	74	690	17.5	163	16	0	48	0.45	2 070	19.30	167	1.56
Sample #6	#3	3:00 PM	0.57	0.00	**19**	8.08	13.0	42	131	17.8	55	12	0	27	0.08	1 660	5.17	142	0.44
Sample #7	#3	4:00 PM	0.00	0.00	**0**	8.13	14.3	38	15	16.3	6	14	0	27	0.01	1 570	0.61	149	0.06
End CSOTF overflow		5:30 PM	0.00	0.00	**0**														
Total				0.07	970				7 049		2 051		1.76		3.33		220.83		15.97
Removal Efficiency (%)									36		18		55		55		42		47

CSOTF overflow estimated at 10 219 m
WWTP Sample = Sample collected and tested by District for NPDES reporting

Bold = Westerly WWTP CSOTF Bypass Lab Results

Table 5. April 12 Water Quality Field Sampling Results (U.S. Customary)

Storm Event #: 1 Average Rainfall 1.1 inches 4/12/97 Unsettled overflow from the CSOTF occurred from 11:17am to 12:49pm.
Average Duration 9 hours 20 minutes Settled overflow from the CSOTF occurred from 9:15am to 5:10pm

Comment	Site	Time	Flow Rate	Incremental Flow	CSOTF Loading	pH	Temp	TSS		BOD		Chromium		Copper		Iron		Zinc	
			(MGD)	(MG)	(gpd/sf)		Deg C.	(mg/l)	(lb)	(mg/l)	(lb)	(ug/l)	(lb)	(ug/l)	(lb)	(ug/l)	(lb)	(ug/l)	(lb)
CSOTF Influent																			
Begin of rain		3:40 AM																	
Begin filling CSOTF																			
Begin of overflow		9:00 AM																	
Initial peak flow		9:45 AM	160.93	3.77															
Sample #1	#1	10:15 AM	123.53	2.87		7.61	7.5	98	5,431	32.6	1,807	20	1.11	67	3.71	1,910	105.85	303	16.79
Peak CSOTF overflow		11:15 AM	282.36	6.47				**69**	**3,723**	**26.0**	**1,403**								
Sample #2	#1	11:45 AM	198.84	4.68		7.77	11.0	628	24,490	208.0	8,111	147	13.66	223	20.73	12,200	1,134.09	896	83.29
Sample #3	#1	12:30 PM	196.20	6.55		7.84	12.3	160	8,742	18.9	1,033	24	1.31	60	3.28	3,500	191.24	215	11.75
Sample #4	#1	1:30 PM	110.91	6.70		7.91	11.4	98	5,477	20.0	1,118	26	1.45	37	2.07	2,800	156.49	206	11.51
Sample #5	#1	2:20 PM	49.50	2.02		7.91	11.8	50	841	15.8	266	12	0.20	24	0.40	1,390	23.38	154	2.59
Sample #6	#1	3:30 PM	4.20	1.01		8.04	12.6	64	541	21.8	184	16	0.14	22	0.19	1,630	13.77	156	1.32
Sample #7	#1	4:15 PM	0.10	0.02		8.05	12.6	70	13	21.8	4	<10	N/A	28	0.01	1,540	0.30	159	0.03
End CSOTF overflow		5:30 PM	0.00	0.09															
Total				34.19					49,260		13,926		17.87		30.38		1,625.12		127.28
CSOTF Quads C&D Effluent																			
Begin of overflow		9:00 AM																	
WWTP Sample		**9:15 AM**	**32.92**	0.34	1,482			**76**	**217**	**31.0**	**89**								
Initial peak/Sample #1	#2	9:45 AM	66.11	1.20	2,975	7.79	9.7	84	844	252.0	2,532	21	0.27	34	0.44	2,500	32.27	202	2.61
Sample #2	#2	11:00 AM	75.02	2.71	3,376	7.80	10.2	72	1,628	35.4	800	19	0.43	32	0.72	2,500	56.53	181	4.09
Peak CSOTF overflow		11:15 AM	123.55	1.29	5,560														
Sample #3	#2	12:00 PM	87.68	2.92	3,946	7.76	9.9	218	7,644	69.5	2,437	67	2.35	85	2.98	5,600	196.37	425	14.90
Sample #4	#2	1:00 PM	81.47	3.67	3,666	7.67	12.5	142	4,346	22.9	701	28	0.86	57	1.74	4,600	140.78	255	7.80
Sample #5	#2	2:00 PM	26.24	1.81	1,181	7.90	12.0	56	843	13.4	202	17	0.26	30	0.45	1,820	27.41	164	2.47
Sample #6	#2	3:00 PM	8.84	0.57	398	8.08	12.5	44	208	18.4	87	14	0.07	22	0.10	1,760	8.33	135	0.64
Sample #7	#2	4:00 PM	0.01	0.06	1	8.00	12.9	50	24	19.1	9	<10	N/A	20	0.01	1,540	0.73	183	0.09
End CSOTF overflow		5:30 PM	0.00	0.03	0														
Total				14.60					15,755		6,857		4.23		6.45		462.42		32.60
CSOTF Quads A&B Effluent																			
Begin of overflow		9:00 AM																	
WWTP Sample		**9:15 AM**	**47.32**	0.49	2,130			**76**	**312**	**31.0**	**127**								
Initial peak/Sample #1	#3	10:00 AM	87.97	2.65	3,959	7.79	7.4	70	1,547	30.3	669	22	0.58	35	0.92	2,170	56.87	212	5.56
Sample #2	#3	11:00 AM	98.57	2.77	4,436	7.93	9.3	66	1,526	35.1	812	16	0.37	36	0.83	2,140	49.48	183	4.23
Peak CSOTF overflow		11:15 AM	158.81	1.65	7,147														
Sample #3	#3	12:10 PM	111.41	3.83	5,014	7.65	10.8	130	5,949	37.2	1,702	36	1.65	56	2.56	3,900	178.46	283	12.95
Sample #4	#3	1:00 PM	102.31	4.74	4,605	7.93	11.4	110	4,351	18.0	712	22	0.87	46	1.82	3,700	146.36	200	7.91
Sample #5	#3	2:00 PM	35.50	2.46	1,598	7.94	12.4	74	1,519	17.5	359	16	0.33	48	0.99	2,070	42.50	167	3.43
Sample #6	#3	3:00 PM	12.90	0.82	581	8.08	13.0	42	288	17.8	122	12	0.08	27	0.19	1,660	11.39	142	0.97
Sample #7	#3	4:00 PM	0.04	0.10	2	8.13	14.3	38	33	16.3	14	14	0.01	27	0.02	1,570	1.35	149	0.13
End CSOTF overflow		5:30 PM	0.00	0.06	0														
Total				19.59					15,525		4,518		3.89		7.33		486.41		35.18
Removal Efficiency (%)									36		18		55		55		42		47

CSOTF overflow estimated at 2.7 MG
WWTP Sample = Sample collected and tested by District for NPDES reporting

Bold = Westerly WWTP CSOTF Bypass Lab Results

R0024798

CSOTF Sampling Events

Overflow Event #1 occurred on April 12. The rainfall amounted to 27.94 mm (1.1 in) over a 9-hour-and-20-minute period. CSOTF experienced an 8½-hour settled overflow and about a 1¾-hour CSOTF overflow. Approximately 22.36 tonnes (24.63 tons) of TSS entered CSOTF and 14.20 tonnes (15.64 tons) left it. CSOTF removed an average of 50 percent of the metals that entered the system.

The second overflow event happened on May 19. Rainfall was intense though highly variable and widely scattered. A CSOTF overflow occurred at the beginning of the settled overflow and lasted one-half hour. Over 21.79 tonnes (24 tons) of TSS entered the system during this event and only 4.54 tonnes (5 tons) left it. Removal efficiency was high as the high-intensity storm flushed the sewer system. The short duration of the overflows allowed the majority of the TSS to be captured in CSOTF. This event showed good removal efficiencies for both TSS and BOD. Metals removal efficiency averaged just under 30 percent.

The May 25 rain event produced 21.08 mm of rain (0.83 in) in over 11 hours. CSOTF reacted with a settled overflow lasting 7½ hours. A CSOTF overflow did not occur. The low flows were apparently not high enough to flush out the system, as only 2.04 tonnes (2.5 tons) of TSS entered the system. The CSOTF removal efficiency of TSS for this event was 2 percent. Removal efficiencies were highly variable.

The fourth CSOTF overflow event happened on May 31. 25.4 mm (1.0 in) of rain fell in just over 12 hours. CSOTF experienced a 33½-hour settled overflow and a 1½-hour CSOTF overflow. The influent loadings of all parameters were low compared to Events 1 & 2. The TSS removal efficiency was 7 percent. A pattern similar to May 25 was observed where settled TSS appears to be resuspended and washed out. The removal efficiencies of the metals are negative, indicating the previously settled metals may have been re-suspended and washed out of the system.

The fifth event closely followed the fourth event. About 21.84 mm (0.86 in) of rain fell in 4¾ hours on June 2. CSOTF was already full. The settled overflow which ended at 2:35 a.m. was restarted at 8:45 a.m. A CSOTF overflow occurred from 8:58 a.m. until 11:44 a.m. The settled overflow continued until 12:55 a.m. on June 3. The sampling analysis shows 5-percent TSS removal. The effluent TSS increased during the event while the influent TSS continually decreased.

The sixth and final sampled event occurred on August 13. Roughly 10.16 mm (0.40 in) of rain fell in 4 hours. CSOTF had a settled overflow event that began at 2:40 a.m. and lasted until 4:00 a.m. The sampling analysis showed 10 percent of TSS was removed. The removal efficiencies of BOD and the metals were all negative, possibly reflecting the use of CSOTF earlier on August 12.

The patterns of CSOTF reactions to the various rain events indicate that the facility removed total suspended solids significantly more efficiently when the loading was greater than 20.43 tonnes (45,000 lbs). For the very low TSS loadings, CSOTF was ineffective. A correlation between low removal percentages and timing of quality sampling does not appear to exist. Flows during the initial portion of an event are generally not sufficient to flush the system. CSOTF removal efficiencies for metals generally were 30- to 50-percent.

DISCUSSION

The six studied events had a total rainfall of 117.09 mm (4.61 in) and a total volume of 872 212 m^3 (230.5 MG). Of the total volume, 558 140 m^3 (147.5 MG) was settled flow through CSOTF, 118 060 m^3 (31.2 MG) overflowed CSOTF, and 238 013 m^3 (62.9 MG) was returned flow to the WWTP. Return flow for the May 31 event was recorded as zero since the WWTP flows did not allow return of stored flow from the May 31 to June 2 rainfall events until after June 2.

Overall, CSOTF removed approximately 35.6 percent of both total BOD and suspended solids load (see Tables 6 and 7). As a combined sewer overflow storage facility, approximately 22 percent of the total CSOTF flow and its associated BOD and suspended solids load was stored and returned to the WWTP.

Table 6. CSOTF Performance Summary - TSS & BOD (Metric)

Date 1997	Rainfall (mm)	Flows (m^3)	Item	TSS In (kg)	TSS Out (kg)	TSS Removed (kg)	TSS %	BOD In (kg)	BOD Out (kg)	BOD Removed (kg)	BOD %
4/12	27.94	129,447	Settled Overflow	22 358	14 195	8 163	36.5%	6 304	5 170	1 134	18.0%
		47,691	Return	4 671	0	4 671	100.0%	1 587	0	1 587	100.0%
		10,220	CSOTF Overflow	2 902	2 902	0	0.0%	862	862	0	0.0%
		187,358	Event Subtotal	29 932	17 098	12 834	42.9%	8 753	6 032	2 721	31.1%
5/19	10.922	34,065	Settled Overflow	22 132	4 853	17 279	78.1%	2 630	816	1 814	69.0%
		47,691	Return	10 295	0	10 295	100.0%	1 224	0	1 224	100.0%
		38,607	CSOTF Overflow	32 653	32 653	0	0.0%	4 036	4 036	0	0.0%
		120,363	Event Subtotal	65 079	37 506	27 574	42.4%	7 891	4 853	3 039	38.5%
5/25	21.082	49,205	Settled Overflow	2 041	1 995	45	2.2%	726	499	227	31.3%
		49,584	Return	2 086	0	2 086	100.0%	726	0	726	100.0%
		0	CSOTF Overflow	0	0	0	n/a	0	0	0	n/a
		98,789	Event Subtotal	4 127	1 995	2 132	51.6%	1 451	499	952	65.6%
5/31	n/a	n/a	Settled Overflow	6 848	6 349	499	7.3%	n/a	n/a	n/a	n/a
		n/a	Return	0	0	0	n/a	n/a	n/a	n/a	n/a
		n/a	CSOTF Overflow	1 497	1 497	0	0.0%	n/a	n/a	n/a	n/a
		n/a	Event Subtotal	8 345	7 846	499	6.0%	n/a	n/a	n/a	n/a
6/2	21.844	218,395	Settled Overflow	17 596	16 780	816	4.6%	2 404	1 950	454	18.9%
		47,691	Return	3 855	0	3 855	100.0%	544	0	544	100.0%
		54,126	CSOTF Overflow	4 898	4 898	0	0.0%	590	590	0	0.0%
		320,211	Event Subtotal	26 349	21 678	4 671	17.7%	3 537	2 540	998	28.2%
8/13	10.16	5,678	Settled Overflow	0.29	0.26	0.03	10.8%	0.16	0.51	(0.35)	-213.9%
		48,448	Return	0.22	0	0.22	100.0%	0.12	0	0.12	100.0%
		0	CSOTF Overflow	0	0	0	n/a	0	0	0	n/a
		54,126	Event Subtotal	0.52	0.26	0.25	49.1%	0.29	0	(0.23)	-79.4%
Total	91.948	436,789	Settled Overflow	70 975	44 173	26 803	37.8%	12 064	8 435	3 628	30.1%
		241,105	Return	20 907	0	20 907	100.0%	4 082	0	4 082	100.0%
		102,952	CSOTF Overflow	41 950	41 950	0	0.0%	5 488	5 488	0	0.0%
		780,846	Event Subtotal	133 833	86 123	47 710	35.6%	21 633	13 923	7 710	35.6%

Table 7. CSOTF Performance Summary - TSS & BOD (U.S. Customary)

Date 1997	Rainfall (in)	Flows (MG)	Item	TSS				BOD			
				In (lbs)	Out (lbs)	Removed (lbs)	%	In (lbs)	Out (lbs)	Removed (lbs)	%
4/12	1.1	34.2	Settled Overflow	49,300	31 300	18 000	36.5%	13,900	11 400	2 500	18.0%
		12.6	Return	10,300	0	10 300	100.0%	3,500	0	3 500	100.0%
		2.7	CSOTF Overflow	6,400	6 400	0	0.0%	1,900	1 900	0	0.0%
		49.5	Event Subtotal	66,000	37 700	28 300	42.9%	19,300	13 300	6 000	31.1%
5/19	0.43	9	Settled Overflow	48,800	10 700	38 100	78.1%	5,800	1 800	4 000	69.0%
		12.6	Return	22,700	0	22 700	100.0%	2,700	0	2 700	100.0%
		10.2	CSOTF Overflow	72,000	72 000	0	0.0%	8,900	8 900	0	0.0%
		31.8	Event Subtotal	143,500	82 700	60 800	42.4%	17,400	10 700	6 700	38.5%
5/25	0.83	13	Settled Overflow	4,500	4 400	100	2.2%	1,600	1 100	500	31.3%
		13.1	Return	4,600	0	4 600	100.0%	1,600	0	1 600	100.0%
		0	CSOTF Overflow	-	0	0	n/a	-	0	0	n/a
		26.1	Event Subtotal	9,100	4 400	4 700	51.6%	3,200	1 100	2 100	65.6%
5/31	n/a	n/a	Settled Overflow	15,100	14 000	1 100	7.3%	n/a	n/a	n/a	n/a
		n/a	Return	-	0	0	n/a	n/a	n/a	n/a	n/a
		n/a	CSOTF Overflow	3,300	3 300	0	0.0%	n/a	n/a	n/a	n/a
		n/a	Event Subtotal	18,400	17 300	1 100	6.0%	n/a	n/a	n/a	n/a
6/2	0.86	57.7	Settled Overflow	38,800	37 000	1 800	4.6%	5,300	4 300	1 000	18.9%
		12.6	Return	8,500	0	8 500	100.0%	1,200	0	1 200	100.0%
		14.3	CSOTF Overflow	10,800	10 800	0	0.0%	1,300	1 300	0	0.0%
		84.6	Event Subtotal	58,100	47 800	10 300	17.7%	7,800	5 600	2 200	28.2%
8/13	0.4	1.5	Settled Overflow	0.65	0.58	0.07	10.8%	0.36	1.13	-0.77	-213.9%
		12.8	Return	0.49	-	0.49	100.0%	0.27	0.00	0.27	100.0%
		0	CSOTF Overflow	-	0	0	n/a	-	0	0	n/a
		14.3	Event Subtotal	1.1	0.6	0.56	49.1%	0.63	0	-0.5	-79.4%
Total	3.62	115.4	Settled Overflow	156,501	97 401	59 100	37.8%	26,600	18 600	8 000	30.1%
		63.7	Return	46,100	0	46 100	100.0%	9,000	0	9 000	100.0%
		27.2	CSOTF Overflow	92,500	92 500	0	0.0%	12,100	12 100	0	0.0%
		206.3	Event Subtotal	295,101	189 901	105 201	35.6%	47,701	30 700	17 000	35.6%

* BOD concentrations for this storm were mostly below detection limit (12 mg/l); thus, calculations could not be performed.

As a primary treatment facility, the CSOTF tanks provided 37.8 percent suspended solids removal and an associated 30.1 percent BOD removal.

Comparing the quantity of solids from the May 19, 1997, storm relative to the other storms is important in evaluating CSOTF performance. The higher peak flows in the May 19, 1997, storm (10.92 mm [0.43 in] of rain) generated more than two times the solids in one quarter the flow compared to the sustained storms of May 31 and June 2 (46.99 mm [1.85 in] of rain). CSOTF solids removal performance at these higher suspended solids loadings was significantly better (78.1 percent) than at the lower suspended solids loadings (4.6 percent). The authors' opinion is that the performance difference relates to a higher concentration of inert materials at the higher loadings but this has not been verified by testing.

CSOTF Loading and Performance Characteristics

A distinct peak loading characteristic was documented for the Westerly District collection system. Peak flows in excess of the CSOTF 13.1 m^3/s (300 mgd) design flow rate appeared to mobilize and convey solids stored in the collection system to the Westerly WWTP. Peak flows of 13.1 m^3/s (300 mgd) and 33.3 m^3/s (760 mgd) for the April 12 and May 19 storms produced peak concentrations of 628 mg/l and 980 mg/l suspended solids and 208 mg/l and 120 mg/l BOD respectively. Over 50 percent of the pollutant loads recorded for these storms were during peak flow conditions.

The May 19 storm was a relatively short duration, widely scattered storm with areas of high rainfall intensity. Rainfall averaged 10.92 mm (0.43 in) with a peak intensity of 70.61 mm (2.78 in) per hour at one rain gauge. The storm produced both the highest peak flow rate through CSOTF of approximately 33.3 m^3/s (760 mgd) and the highest total suspended solids loading of the storms evaluated. This storm generated over 48 percent of the total suspended solids recorded during the evaluation period.

Following peak suspended solids loading conditions, a period of solids carry-out was noted. Effluent concentrations were elevated for 2 to 4 hours following a peak influent loading condition. A shorter period of solids carry-out was also noted when flows increased later in a storm event.

CONCLUSIONS

As a result of the CSOTF performance evaluation, future CSO treatment options should consider improving inlet hydraulic conditions and using lower peak design loading rates. In-system options should be considered to minimize the peak flow/peak loading condition impacts. In-system options should include identification of low-velocity sewers and areas that may accumulate suspended solids during dry weather conditions for replacement or periodic flushing and optimizing treatment plant influent flow control.

ACKNOWLEDGMENTS

The authors would like to thank the operations staff at the District's Westerly WWTP for their work in coordinating with the evaluation sampling personnel, providing plant performance data, and reviewing the CSOTF performance conclusions.

The flow monitoring and quality sampling program involved the District, Metcalf & Eddy (M&E), Dodson-Stilson, Inc. (DSI), ADS Environmental Services, Inc., Enviromatrix Labs and Adams Laboratory. District plant personnel provided daily logs, results from standard water quality sampling and interpretation of operations. DSI provided field services to take the water quality grab samples and collect the automatic samples. Samples were analyzed for bacteria by Adams Laboratory and for all remaining parameters by Enviromatrix Labs. ADS provided, installed and maintained the flow meters throughout the project. M&E coordinated the field and laboratory efforts. Data was submitted to M&E for use in the system analysis.

GLOSSARY

Settled Overflow: A CSOTF event in which settled flow goes over the quadrant weirs to Lake Erie.

CSOTF Overflow: The portion of flow that passes through the center channel bypass gates directly to Lake Erie.

Return Flow: The quantity of combined sewer system overflow retained in the CSOTF and NWI and returned to the Westerly WWTP for full treatment.

STORAGE/SEDIMENTATION FACILITIES FOR CONTROL OF STORM AND COMBINED SEWER OVERFLOWS: DESIGN MANUAL

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ABSTRACT

This paper summarizes a report of the same title (Stallard *et al.*, 1998), which describes applications of storage facilities for wet-weather flow (WWF) control and also presents step-by-step procedures for the analysis and design of storage-treatment facilities. In both the report and this paper, retention and detention storage, and sedimentation treatment are classified and described. Retention storage facilities capture and dispose of stormwater runoff through infiltration, percolation, and evaporation. Detention storage is temporary storage for stormwater runoff or combined sewer overflow (CSO). Stored flows are subsequently returned to the sewerage system at a reduced rate of flow when downstream capacity is available, or the flows are discharged to the receiving water with or without further treatment. Sedimentation in storage basins alters the WWF stream by gravity separation. The stormwater runoff and CSO must be characterized to estimate the efficiency of any sedimentation basin. International as well as national state-of-the-art technologies related to storage and sedimentation treatment are discussed.

KEY WORDS

wet weather flow, sedimentation, detention storage, retention storage, combined sewer overflow, stormwater

INTRODUCTION

Among the earliest examples of public works are urban drainage systems designed to convey urban storm flow or WWF away from populated areas to receiving waters. WWF may consist of stormwater alone, or it may consist of both stormwater and sanitary or domestic wastewater in combined sewer systems, which is known as CSO when it overflows. Discharges from WWF conveyance systems have significant impacts on receiving-water quality. Recognition of their significance has increased as the quality of effluents from municipal wastewater treatment plants has improved as a result of the Clean Water Act. National cost estimates for controlling pollution from WWFs are substantial. As reported by the U.S. Environmental Protection Agency (EPA) (Field *et al.*, 1996), the cost of meeting water quality standards for stormwater discharges has been projected to be as high as $400 billion in capital costs and $540 billion/year in operation and maintenance (O&M) costs. Capital costs for CSO abatement are estimated to be more than $50 billion for eleven hundred communities served by combined sewer systems.

The variable nature of WWFs makes controlling them difficult. Transport and treatment facilities for controlling excess WWF, which generally are designed to handle medium-intensity, medium-duration storm-flow volumes, are frequently idle during dry periods and overflow during large storms. Temporary storage of excess WWF can be an effective and economical method of controlling flooding and pollution. Excess WWF stored during large storms or during more intense rainfall periods can be released slowly when capacity in the drainage and treatment system is available. As a result, overflows occur less often than they would without this storage.

PLANNING METHODOLOGY

The solution to WWF problems is most often a combination of various best management practices (*i.e.*, nonstructural and low-structurally-intensive alternatives) and unit process applications (*i.e.*, physical treatment for removal of settleable and suspended solids and floatable material). Storage and/or sedimentation facilities are and should be the backbone of such an integrated WWF management plan. The following are the elements of planning a storage or sedimentation facility:

- general planning conditions,
- establishment of treatment goals,
- planning methodology,
- cost optimization methodologies,
- storage-volume determination methods,
- effect of storage and/or sedimentation, and
- integration with existing system.

General planning conditions include determining whether storage or sedimentation is the best solution for dealing with the problems involved in terms of the type of WWF and the treatment goals. The feasibility of locating such a facility must be examined. **Treatment goals** include, but are not limited to, the maximum number of yearly overflow events, maximum overflow volume, and desired detention time.

Figure 1 illustrates the planning methodology for source control options. The basic **planning methodology** includes the following steps:

- identify functional requirements,
- identify site constraints,
- establish basis of design,
- select storage and/or treatment option,
- estimate costs and cost sensitivities,
- evaluate option for compliance with treatment goals, and
- refine and complete or modify and repeat.

The **cost optimization methodologies** used for storage or sedimentation facilities depends on the purpose of the facility: flow control only, or a combination of flow control and pollutant reduction. The Mass-Diagram Method should be used for flow control facilities, and the Production Theory Method should be used for flow control and pollutant reduction facilities. Both of these methods are described in the report.

Storage-volume determination methods demonstrate the effect of different possible combinations of storage and/or sedimentation design parameters (*e.g.*, settling time and facility size) on flow control. Methodologies for approaching these calculations include the following: desktop hand computations; statistical analysis of rainfall and flow data; simple, continuous simulation of WWF systems; and detailed, continuous or single event simulation of WWF systems. Deciding on the approach to be used depends on the size and complexity of the drainage area and/or sewerage system. For small and simple systems, hand computations can be used. For large and complex systems, computerized continuous simulated models can be used.

To evaluate the **effect of storage/sedimentation** alternatives being considered, the degree to which they achieve the goals developed must be compared. Cost and performance of each should be considered. Thus, the best apparent alternative should be the most cost-effective one meeting the technical goals established.

Integration of a storage or sedimentation facility with an existing sewerage or drainage system involves selecting control methods that are both applicable to and compatible with the existing facilities and goals. The following steps should be taken: identify existing components and function, establish system needs, identify applicable control alternatives, and determine control method compatibility.

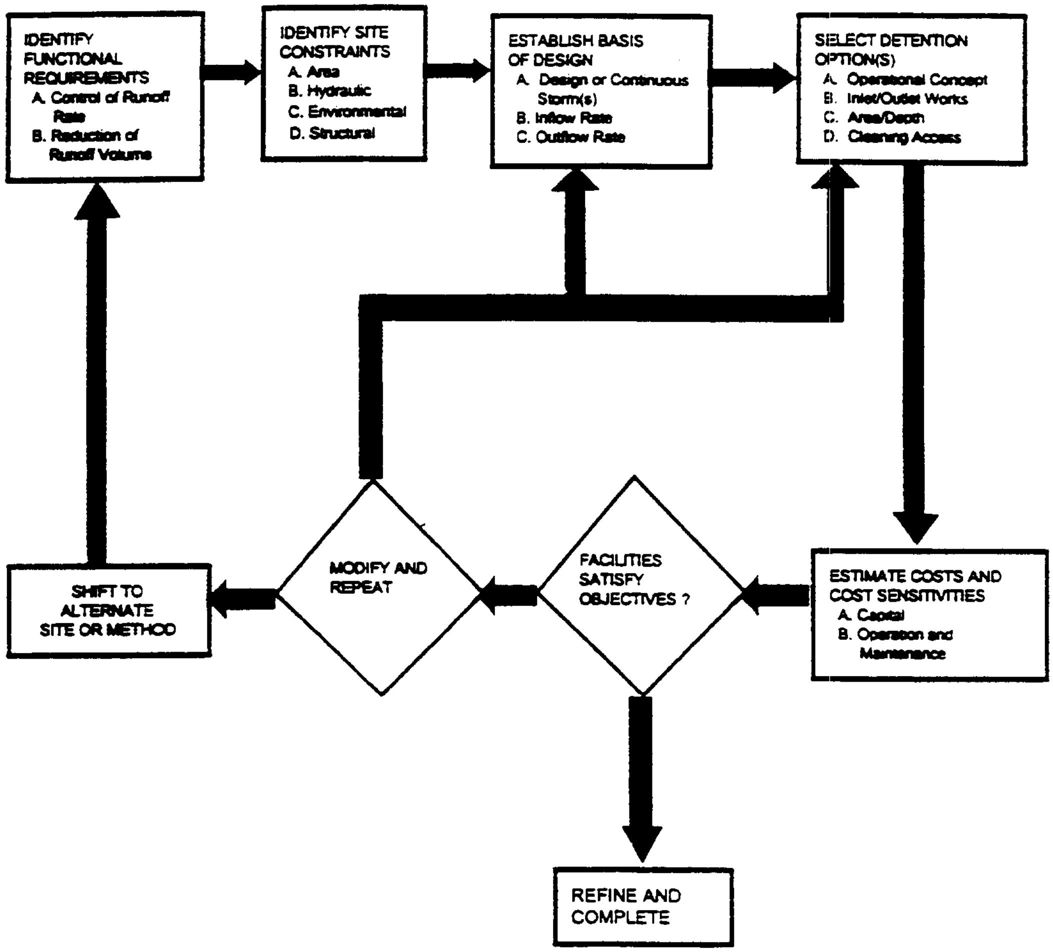


Figure 1. Source Control Planning Methodology

FACILITY DESIGN

The main steps to be followed in designing storage/sedimentation facilities for both combined sewer and separate storm sewer systems are:

- identifying problem,
- identifying data needs,
- determining the pollution load,
- identifying the flood control and pollutant removal objectives,
- optimizing control effectiveness,
- conducting a pollutant budget analysis,
- determining an operating strategy, and
- selecting the instrumentation and control strategy to be used.

Design of Retention Storage Facilities Stormwater retention is the storage of excess runoff for complete removal from the surface drainage and discharge system. The water collected percolates through the bottom of the retention facility and may reach the groundwater. Stormwater retention facilities may take a variety of forms, such as ponds and perforated culverts. This section describes design procedures and operation considerations for the most common retention storage facility types – dry and wet ponds.

Size and location are important design considerations for both types of ponds. Size requirements include not only volumetric capacity but also surface area and soil interface area requirements. The **pond configuration** depends on:

- the runoff storage volume needed,
- the surface area, configuration, and weir length required to assure adequate settling during sedimentation operation,
- the surface area needed for adequate transfer of oxygen into the pond water to allow aerobic decomposition of organic pollutants,
- the soil-water interface area needed for adequate percolation of stored runoff between storm events, and
- the area needed to serve whatever multiple uses the basin may have.

The suitability of a site within a drainage area for **locating a retention pond facility** depends on:

- site availability,
- compatibility of surrounding land uses with a stormwater retention facility and its other functions,
- the area required,
- soil permeability,
- tributary catchment size, and
- the site's relationship to other sewer or drainage facilities.

The procedure presented for **design of retention facilities** consists of the following steps:

- quantify functional requirements,
- identify waste load and flow reduction,
- determine preliminary basin size,
- identify feasible pond sites,
- investigate most promising sites,
- establish basin sizes,
- design solids removal facilities, and
- determine pond configuration.

The approach, which should make use of existing experience, known concepts, or developed theories, must be integrated to insure that the desired functions of the ponds (sediment removal, infiltration and percolation, flood control, or flow reduction) are compatible with the type of flow reaching the pond (stormwater runoff or CSO) and any other multi-use aspects (recreation, irrigation, aesthetics, etc.). In actual practice, retention ponds are very seldom used for CSOs because the organic solids tend to seal the pond bottom and reduce the soil infiltration capacity.

The efficiency of retention ponds in reducing stormwater pollutant loadings depends heavily on the underlying soil as a treatment medium. The mechanisms of removal include settling, filtering, biological activity, coagulation, adsorption, and chemical reaction. The major operational problems with ponds center around handling captured solids. Other operational concerns are the inlet and outlet structures, maintenance of vegetative cover through alternating wetting and drying periods, insect control, odor control, and maximizing availability of the pond for alternative uses. Pond construction costs can be estimated from graphs that show the costs for either area or storage capacity required such as the 1979 and 1980 figures presented in the report. Operational costs must be estimated on a site by site basis.

Design of Detention Storage Facilities Detention storage delays excess runoff and attenuates peak flows in the surface drainage system. During peak flows, detention storage holds excess water until the inflow decreases and releases it during low-flow periods. Because of sedimentation that occurs during detention, detention storage in tanks or basins can also be considered a treatment process for high storm flow volumes that create tank or basin overflow. Site constraints to be considered for detention storage facilities include tributary area, topography, local land use, and area available for the structure or basin.

The types of detention storage include onsite and in-system. Onsite detention is the detention of stormwater or CSO at the source before it reaches a sewer network or receiving water. Onsite detention occurs in natural ditches, open ponds or basins, rooftops, parking lots, or recreational facilities. In-system detention storage holds storm flow either in series or in parallel within the collection system. In-system detention storage includes inline storage and offline storage. Inline storage can be accomplished by using the available volume in trunk sewers, interceptors, wet wells, and tunnels to store excess WWF. Excess flows are stored off line in open or covered basins, caverns, mined labyrinths, and lined or unlined tunnels. Functionally, the application of onsite detention differs little from in-system storage other than the location where the storage occurs. However, while onsite detention is used primarily to minimize the cost of constructing new storm sewers to serve a developing area, in-system storage is generally used to decrease the frequency and volume of overflows from combined sewer systems.

Factors to be considered in the design of **onsite detention storage** facilities are:

- tributary area,
- storage area and volume,
- structural integrity, and
- responsibility of the owner.

Factors to be considered in the design of **in-system detention storage** facilities are:

- size and slope of sewers,
- peak flow rates,
- controls required for system operation, and
- resuspension of sediment.

The **design methodologies for onsite storage and in-system storage** are very similar and consist of the following steps:

- identify functional requirements,
- identify site constraints,
- establish basis of design,
- select storage options and locations,
- estimate costs, and
- complete design.

The construction costs for in-system storage have been reported for selected demonstration sites. Since construction costs are highly site specific, they are not very useful as a basis for estimating costs. These costs also vary considerably depending on the complexity of the flow regulators and control systems. Detailed O&M cost data are limited. O&M costs must be estimated for specific facilities from the operation plan and maintenance schedule.

Design of Sedimentation Facilities Sedimentation in storage basins, commonly referred to as storage/sedimentation, alters the WWF stream by gravity separation. Storage/sedimentation is the most commonly and, perhaps, most effectively practiced method of urban CSO and stormwater runoff control in terms of the number of operating installations and length of service. Conversely, storage/sedimentation is frequently criticized for lack of innovation because of its simplicity and high cost due to size and structural requirements.

Functionally, the applications of downstream storage/sedimentation facilities vary from essentially total containment, experiencing only a few overflows per year, to flow-through treatment systems where total containment is the exception rather than the rule. For total containment, the major concerns are the large storage volume, the provisions of dewatering, and post-storm cleanup. For flow-through treatment systems, performance hinges on treatment effectiveness and design considerations including loading rates, inlet and outlet controls, short circuiting, and sludge and scum removal systems. In the case of offline facilities, the option exists to selectively capture the portion of storm flow with the highest pollutant load, referred to as the first flush, and bypass the balance of the flow to avoid the discharge of much of the pollution.

Factors to be evaluated in the design of storage/sedimentation facilities include the following:

- storage volume,
- treatment efficiency,
- need for disinfection, and
- site constraints.

The following are **storage/sedimentation facility design procedures**:

- identify functional requirements,
- identify site constraints,
- establish basis of design,
- select sedimentation facility configuration,
- identify and select pretreatment,
- determine auxiliary systems needed,
- estimate costs and conduct cost-effectiveness analysis, and
- complete design.

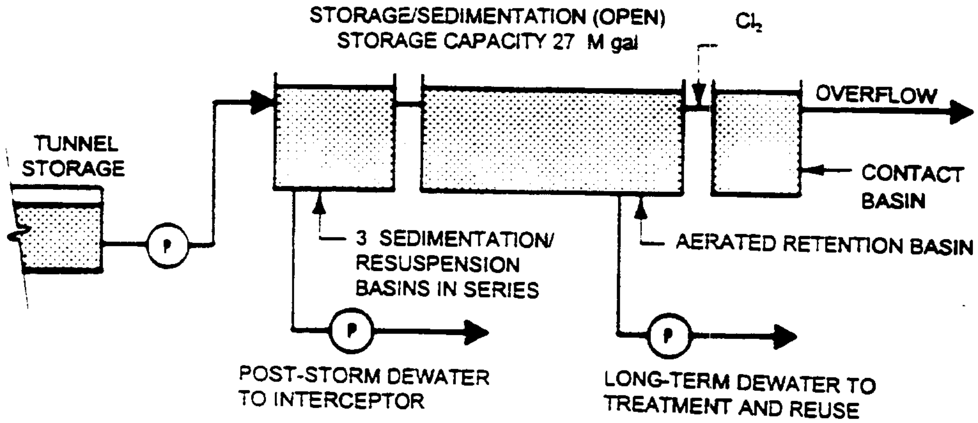
The major O&M goal of downstream storage/sedimentation basins is to provide a facility that is available to its full design capacity as long as needed. Secondary goals include clear, prompt, and complete records of performance, reliability to provide for real location of personnel and facilities in non-storm periods, and dual-use operations, such as, backup treatment and/or flow equalization for dry-weather plants. The O&M requirements and procedures should be developed from the operational plan; there are no industry-wide standards.

The report presents detailed design considerations and procedures for downstream storage/ sedimentation basins, which are illustrated by example and through references of designed and operated facilities. Cost information is also provided. Examples of representative CSO storage/sedimentation basins and auxiliary support facilities are shown in Figure 2.

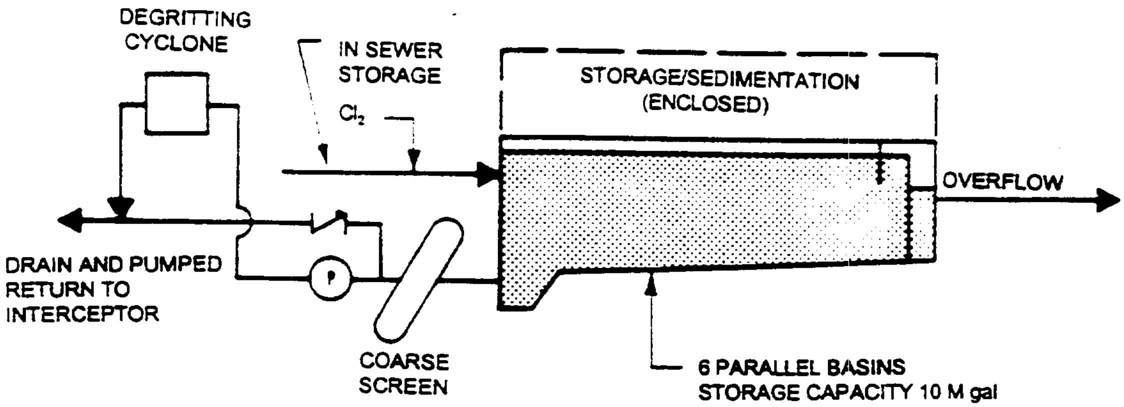
INTERNATIONAL PERSPECTIVE

The application of storage/sedimentation controls for urban WWF problems is not unique to the United States. In this era of excellent communications and increasing technology-sharing on an international scale, similar approaches are found in many areas of the world. Several technologies developed internationally are introduced including flow-control devices developed in Sweden, Denmark, and Germany; an in-receiving water flow balancing system developed and applied in Sweden; and an innovative self-cleaning storage/sedimentation basin used in Zurich, Switzerland.

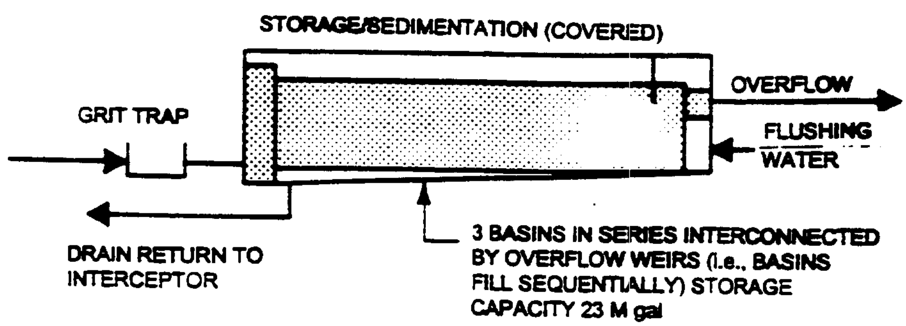
For certain cases, the flow from storage/sedimentation facilities can be controlled by means of specially-designed flow-control devices, which provide more effective flow control than can be accomplished with conventional static devices. An advanced static device, the Steinscruv flow regulator, developed in Sweden in the 1970s by Stein Bendixsen, consists of a stationary, anchored, screw-shaped plate that is installed in a pipe. In that part of the plate which fits against the bottom of the pipe, there is a bottom opening to release a specified base dry-weather flow. The Hydrobrake, developed in Denmark in the mid-1960s, is used to control outflows from storage structures. Hydrostatic pressure associated with the water level controls the rate of flow through this device. A device with a similar operating principle, the Wirbeldrossel or turbulent throttle, developed in Germany in the mid-1970s, also regulates flow from a storage facility. Another flow regulator valve, developed in Sweden in the late 1970s, is a central outlet pipe surrounded by a pressure chamber filled with air. Water pressure on the upper portion of the device



MOUNT CLEMENS, MICHIGAN



NEW YORK CITY (SPRING CREEK), NEW YORK



SACRAMENTO (PIONEER RESERVOIR), CALIFORNIA

Figure 2
Representative CSO Storage/Sedimentation Basins and Auxiliary Support Facilities

displaces the fabric at the outlet, which controls the discharge volume.

The Flow Balance Method, an innovative approach to urban WWF treatment for the protection of lakes, has been developed and applied at several locations in Sweden by Karl Dunkers. Also being used in other locations, the Flow Balance Method uses a portion of receiving-water volume within a hanging curtain to store runoff, while allowing for suspended solids sedimentation, before discharge.

Typically, removal of settled solids from an inline storage facility has been a problem that requires an auxiliary flushing system of some sort. An innovative approach to eliminating this problem has been implemented in Zurich, Switzerland. A continuous dry-weather channel, which is an extension of the tank's combined sewer inlet, is formed by a number of parallel grooves connected at their end points. Any solids that have settled in the basin during its storage operation are resuspended by the channelized high-velocity flow during the drawdown following a storm event.

ACKNOWLEDGMENT

The authors acknowledge the efforts of the authors of the full report: W. Michael Stallard, William G. Smith, Ronald W. Crites, and John A. Lager. Ramjee Raghavan and Helen Egidio provided support for developing the figures.

DISCLAIMER

The full report (Stallard *et al.*, 1998) was drafted between September 1979 and October 1981 by Metcalf & Eddy, Inc., under the sponsorship of the U.S. Environmental Protection Agency's Office of Research and Development in Cincinnati, Ohio, in partial fulfillment of Contract No. 68-03-2877. Along with this paper, the 1998 revision is being released currently to provide information to communities in support of their stormwater and CSO management efforts. Despite the revision, some of the content may no longer be entirely current.

REPORT AVAILABILITY

Copies of the report are available from the National Technical Information Service (Order No. PB98-132228), which can be contacted via the EPA's National Risk Management Research Laboratory Wet Weather Flow Home Page at "www.epa.gov/ednnrmrl/".

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COMPUTER MODELING FOR DESIGN AND PRACTICAL PURPOSES
Combined Sewer Overflow Abatement Program - Monroe County, New York

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INTRODUCTION

Monroe County has a long standing history of being at the forefront of protecting water quality and enhancing the recreational use of area surface waters. In the early 1970's, Monroe County had begun developing one of the first Combined Sewer Overflow Abatement Programs in the nation. During the planning phases of the program, several abatement technologies were evaluated with a deep-rock tunnel storage and treatment system being selected for construction. Continuing Monroe County's philosophy of improving the protection of water quality, enhanced methods of operation and maintenance of the storage and treatment system are being developed.

Monroe County and its consultants recognized the value of the mathematical models used during the planning and design phases of the program. The huge modeling effort put forth during the early 1970's is being brought forward to the 1990's to assist in the development of an operations model. This work increases the value of the initial modeling efforts by facilitating the development of an operation and maintenance model to enhance the day-to-day operation of the system.

HISTORY OF THE SYSTEM

In December 1976, the Wastewater Facilities Plan for the Rochester Pure Waters District's Combined Sewer Overflow Abatement Program (CSOAP) was completed by a joint venture of Erdman Anthony Associates; Lozier Engineers, Inc.; and Seelye Stevenson Value & Knecht, Inc. This plan contained recommendations for a deep-rock tunnel storage system for storing and conveying combined sewage overflowing from various points in the surface sewer system.

The final plan included the design and construction of a 33 mile network of deep-rock tunnels, 54 drop shafts, five control/relief structures, a bridge, and wastewater treatment facility upgrades. The service area for Monroe County's Rochester Pure Waters District encompassed more than 10,000 urban acres.

The design basis for determining the amount of storage volume and level of pollution abatement for the tunnel system included an analysis of the quantity and quality of overflows from the surface sewer system. This analysis was based on historical rainfall events and their effect on established water quality standards for the local receiving waters. The volumes of overflow from each rainfall event were calculated through the use of the Hydrograph-Volume Method (HVM) Model and the Quantity-Quality Simulation (QQS) Model developed by Dorsch Consult Ltd. of Munich, Germany.

The effective storage volume recommended in the 1976 Facilities Plan was approximately 10 million cubic feet. This related to approximately 2 water quality contraventions per year.

Subsequent to the review of this methodology by the United States Environmental Protection Agency (US EPA) and New York State Department of Environmental Conservation (NYS DEC), the size of the project was reduced by establishing an effective target volume of 6.3 million cubic feet of storage. This volume related to approximately 3.5 water quality contraventions per year. This target volume was contingent upon the results of hydraulic analyses of the tunnel system to determine the sensitivity of the tunnel volume on the dynamic performance of the system and the effect on water quality.

The study report for the 1976 Facilities Plan was published in eight volumes. Each of the volumes presented the data, methodology, results, conclusions, and recommendations of its respective study task.

The subject of each volume were Volume I - Planning Analysis; Volume II - Network Analysis; Volume III - Overflow Quantity-Quality Analysis; Volume IV - Receiving Water Quality Study; Volume V - Geotechnical Report; Volume VI - Infiltration/Inflow Study; Volume VII - Environmental Assessment Statement; and Volume VIII - Network Analysis Data. The study conducted for the 1976 Facilities Plan represented a huge planning effort where extensive hydrogeometric data (land surface characteristics) and hydraulic data (sewer network characteristics) for the vast majority of the Rochester Pure Waters District's surface sewer system were developed.

During the design, technical questions had to be resolved involving the behavior of flows in the proposed tunnel system. The tunnel system would be receiving substantial inflows at various points within the system. Depending on the path of any given storm, these inflows would be proceeding both upstream and downstream within the tunnel system. Also, at any given point in time, some portions of the tunnel system could be partially full while other portions of the system are pressurized. These conditions could induce severe pressures in the system that could cause damage to the tunnel or cause geysering of flows back up the drop shafts.

The St. Anthony Falls Hydraulic Laboratory (SAFHL) of the University of Minnesota and Dr. Charles C. S. Song were retained to develop a mathematical mixed flow hydraulic transient model for the tunnel system. The model could accurately simulate the actual process of pressurization and depressurization during the filling and emptying periods of the tunnels. It traced the pressurization surges and calculated flow and pressure at every node along the system continuously throughout a simulation.

The purpose of Dr. Song's model was to assist in the preliminary geometric design and to analyze hydraulic transient effects on the proposed tunnel system. Larger diameters were recommended in certain tunnel sections to reduce the potential for hydraulic transients such as geysering, column consolidation, water hammer, excessive backflows, and to attenuate peak hydraulic pressures generated in the system. From a hydraulic stability standpoint, the analysis indicated that 11.3 million cubic feet of static storage was required for proper hydraulic performance of the proposed tunnel system and to meet the water quality goals set for the program.

The federal grant programs of the 1980's made the construction of the CSOAP Tunnel System possible. To date, the wastewater treatment facility upgrades and 30 miles of the originally planned 33 miles of the tunnel system with associated dropshafts and control structures have been constructed and are in operation. All combined sewer overflow discharge points to local receiving waters have been redirected to the tunnel system. A schematic plan of the CSOAP Tunnel System is presented in Figure 1.

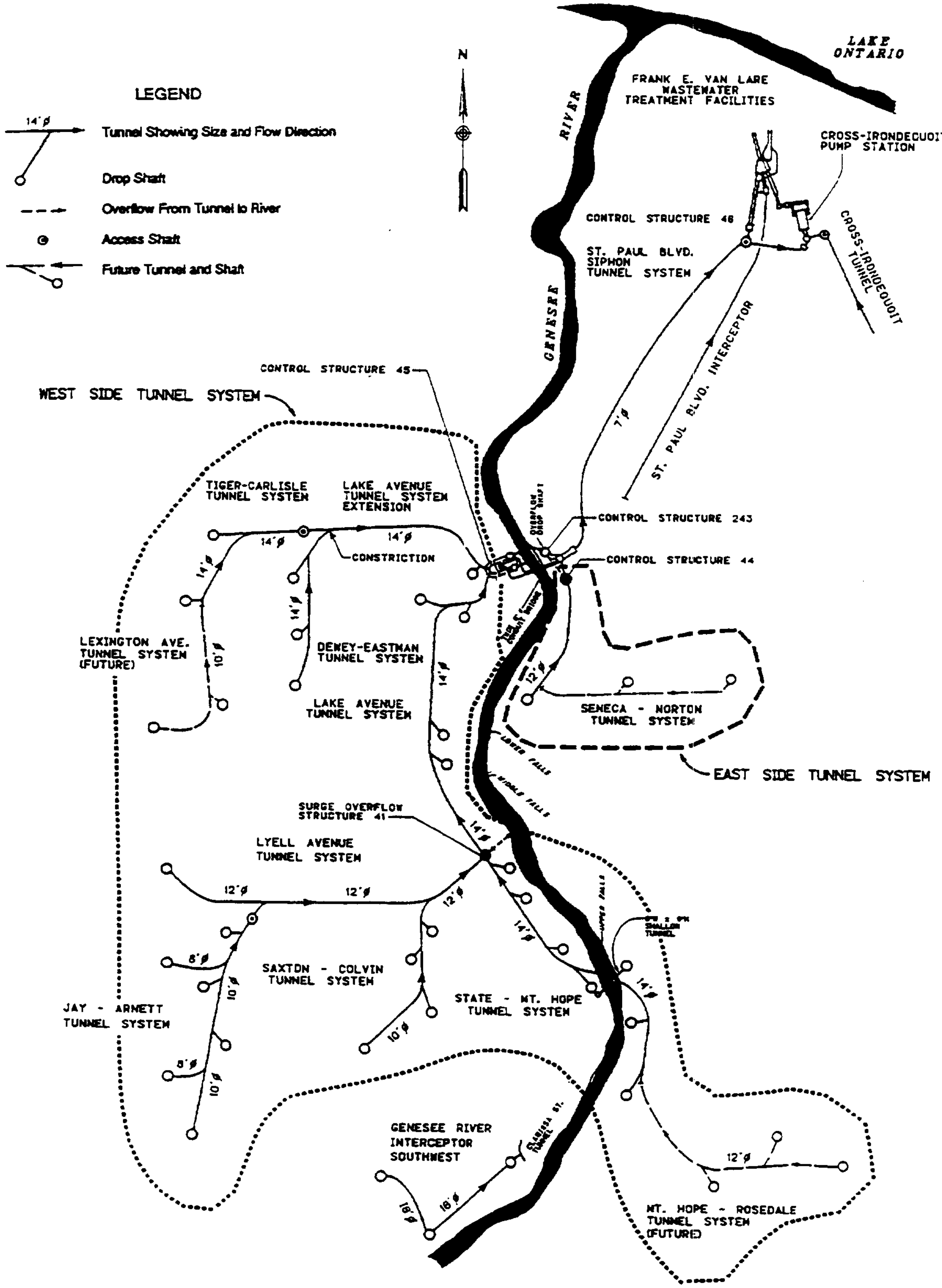
THE DISCOVERY

A condition of the federal grant required Monroe County to complete the estimated $750 million project regardless of the status of the availability of federal funds in future years. By the early 1990's, the federal grant program had essentially ended, leaving three segments of the tunnel system unconstructed. These three segments represented approximately 15 percent of the originally planned volume for the tunnel system. Monroe County was facing the financial issue of locally financing approximately $75 million of additional tunnels.

Monroe County suspected that the portion of the tunnel system which was already constructed, could meet the water quality goals originally set for the program. These suspicions were based on the following: constrictions in the surface collection system were attenuating the design peak inflows to the tunnel system; portions of the tunnel system were constructed to diameters larger than designed due to favorable competitive bidding; and operational strategies were refined as operators gained experience with the system.

The hydraulic stability of the tunnel system is related to the conveyance capacity of the tributary sewer network and the resulting rate of flow entering the tunnel system. Dr. Song's original modeling work was based on flow rates for a long-range future condition where the entire tributary system would be upgraded to eliminate in-system flow restrictions. The implementation of these surface improvements was not part

Figure 1. **Schematic Plan of CSOAP Tunnel System**



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of the program and was to be accomplished over an extended period of time. Some improvements have been made, but most have not. Therefore, the rates of inflow to the tunnel system for which the effective storage was designed have not yet been achieved, and all the effective volume may not be required until those improvements are made.

Proving Monroe County's theory required development of revised inflow hydrographs, representing the existing tributary sewer network, for selected drop shafts. It also required the development of a model to simulate the hydraulic performance of the existing tunnel system.

The original model of the tributary sewer network was completed using the HVM and QQS models on a mainframe computer. This work was well documented in hard copy format, with the majority of the design variables and calculations detailed in the study report. Almost twenty years later, the original HVM and QQS models used in the 1976 Facilities Plan were unavailable. The original model was recreated on a PC platform using the US EPA's Storm Water Management Model (SWMM) to develop the revised inflow hydrographs. The superior documentation and verification of the original modeling work greatly facilitated the recreation in a fraction of the time. The subsequent modeling work using SWMM was again well documented, this time in electronic format.

The effective storage volume and hydraulic performance of the constructed portions of the tunnel system were analyzed using an improved version of Dr. Song's mixed flow hydraulic transient model based on the revised inflow hydrographs.

A revised water quality contravention analysis, similar to that presented in the 1976 Facilities Plan, was conducted to assess the performance of the existing tunnel system in abating combined sewage overflows. The analysis indicated that the constructed tunnel system volume and configuration meets the water quality goals (3.5 contraventions per year) associated with the target volume set by the US EPA and NYS DEC for the program. The unconstructed portions of the tunnel system are not presently needed provided the water quality classification of the receiving waters remains unchanged and until extensive improvements are made to the tributary sewer network.

A secondary goal of the program was to minimize surface flooding and reduce the frequency of basement backups. The performance of the tunnel system, as constructed, has reduced the occurrence of flooding and backups. Currently, there are no plans to make additional major improvements to the tributary sewer network. However, over an extended period of time, the tributary sewer network will undoubtedly be upgraded and inflows to the tunnel system will increase. Larger inflows will eventually result in increased hydraulic pressures generated in the tunnel system and increase the potential for adverse hydraulic transients. The need for additional facilities will be evaluated when significant changes to the tributary sewer network are proposed, when additional inflows are directed to the tunnel system, or when changes are made to the water quality classification of the local receiving waters. Hence, the analysis models originally developed in the 1970's and recreated in the early 1990's, will be used again at some point in the future.

WHAT WAS LEARNED

Monroe County's Combined Sewer Overflow Abatement System consists of a network of deep-rock tunnels. These storage-conveyance tunnels are an extension of the wastewater treatment system. The operational objectives of the total system can be expressed as follows:

- Provide the maximum level of treatment for all flows through the treatment system prior to discharge to the local receiving waters.
- Minimize both the number of combined sewage overflow events and the volume of combined sewage discharged into the more sensitive local receiving waters.
- Minimize the cost of operating and upgrading the system to meet future needs.

The studies of the early 1990's highlighted the interdependence between the surface sewer system, storage tunnels, and treatment system. A more in-depth understanding of the relationship between the surface sewer system efficiency, storage volume, treatment rate, and impact on water quality will improve Monroe County's ability to maintain the objectives of the combined sewer overflow abatement system.

These studies have also brought to light the importance of the real-time operation and control strategies which are currently being employed, and their potential effect on water quality. There are two systems which aid in the operation of the tunnel and treatment systems, the Supervisory Control System (SCS), and the Data Acquisition System (DAS). These systems combine to form a supervisory control and data acquisition (SCADA) system and provide operational recommendations as flow rates and levels are detected. The various set points defined in the SCS can then be modified, but this modification is made after the flow rates or levels have already been observed. These systems do not provide forecasting of anticipated storm flows for the specific event to allow operators to make modifications which would enable them to better utilize the treatment plant and tunnel system, maximize the level of treatment, and minimize overflows.

The flow regime in the tunnel system can be very dynamic. Pressurization surges can move both upstream and downstream within the system. Some portions of the tunnel system can be partially full while other portions of the system are pressurized. During the course of the studies of the early 1990's, it was revealed that only five sensors measuring water depth, in a 30 mile tunnel system, were used by the operators to indicate the tunnel system's storage status. Four of the sensors were located at the downstream end of tunnel subsystems.

A real-time model which integrates the tunnel system operations with the treatment plant's ability to accept flows would help in the evaluation of a multitude of storm flow conditions.

REAL-TIME APPROACH

Monroe County is currently in the process of the phased development of a real-time Operations/System Management Model. This operations tool will: show the current status of the system based on real-time data measured within the system; forecast the status of various portions of the system into the near future during a rain event, based on current status and current rainfall; and suggest operational strategies to reduce the frequency and magnitude of overflows and maximize the degree of treatment for all wastewater discharged to the local receiving waters.

The first phase of the Operations/System Management Model development consisted of the refinement of a storage volume model for the tunnel system, giving real-time tunnel storage status and the instantaneous rate of filling or emptying. The storage and rate of increase or decrease of storage data for each tunnel subsystem is provided by sensors measuring water depth at various locations. Because the filling process is very dynamic, characterized by the existence of surges, a single depth measuring device is not sufficient to provide the knowledge of storage in a tunnel subsystem. Depth information at two or three locations in a tunnel subsystem with an associated empirical equation, relating the multiple depth data with storage volume, was necessary. These empirical equations were derived from the output of Dr. Song's mixed flow hydraulic transient model operating under a range of storm inflow conditions.

The real-time data obtained from the depth sensing devices will be conveyed to a central control room via a combination of telephone lease-lines, radio, and a fiber network. The empirical equations will be incorporated into a graphical user interface where the operators will be able to monitor the status of the tunnel system throughout the course of a rain event. The first phase of development is nearly complete and is scheduled to be operational in 1998.

WHAT'S NEXT

The second phase of the Operations/System Management Model development will incorporate a network of rain gauges into the model. This will give the model the capability to predict what the tunnel storage status will be in the near future during a rain event, thus giving operators additional response time to make adjustments to the system. The relationship between rainfall intensity versus measured tunnel inflow at key locations, and tunnel inflow versus near future tunnel storage status will be developed. This will improve the model's accuracy in predicting storage status and an estimated time to overflow/empty, based on rainfall.

This phase will also include the development of objective functions specific to the tunnel system. The goal of the objective functions will be to optimize the storage capabilities of the existing system. Key control issues that the objective functions will address include simultaneous operation of control structures, diversion of flows within the tunnel system, and diversion of flows within the surface system.

The third phase will involve the development of the treatment portion of the Operations/System Management Model and incorporating the model developed in phase two, into the framework of the overall model. This framework will consist of a model composed of several algorithms and subroutines representing the treatment plant, the tunnel system, major pump stations, and interceptors. It is envisioned that the treatment portion of the model will include each liquid treatment unit process within the plant and their associated treatment efficiencies versus hydraulic capacities. An objective function will be developed for the storage/treatment/overflow decisions to minimize the impact of overflows on the most sensitive receiving waters.

CONCLUSIONS

Modeling of wastewater collection systems began as a way to analyze and design the hydraulic performance of systems. When these models are correlated with actual flow data and modified to compute in real-time, they are very useful operational and maintenance tools. Modeling to improve operation and maintenance is seen as a growth area.

Monroe County has demonstrated that design models can be modified to compute in real-time to be effective operational and maintenance tools. This effort was greatly facilitated through the use of well documented planning studies and record drawings.

Modeling completed for the Monroe County system is growing from predicting what has happened to being able to predict what will happen. This will improve the operational and maintenance function, and the quality of the receiving waters. It is the way of the future.

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IMPACTS OF SEASONALLY VARYING MODEL PARAMETERS ON PREDICTING COMBINED SEWER OVERFLOWS

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ABSTRACT
The most recent release of the City of Detroit's regional sewerage collection system model includes refinements and improved characterizations of various model parameters such as rainfall dependent inflow and infiltration (RDI/I) and dry weather flow (DWF). After these improvements to the model were implemented, the Michigan Department of Environmental Quality (MDEQ) requested that the parameter uncertainty impacts on model results be evaluated. As part of this evaluation, the seasonally varying parameters were evaluated to assess the impacts of temporal distribution. A simplified approach for evaluating the temporal distribution in seasonally varying parameters was used by comparing model results of annually averaged value conditions and seasonally varying value conditions. The characterization of RDI/I, DWF, and evaporation are discussed followed by an evaluation of the impacts of these seasonally varying parameters on model results with respect to the annual averaged values.

KEYWORDS
dry weather flow, rainfall dependent inflow and infiltration, evaporation, seasonal variation, modeling, combined sewer overflow

INTRODUCTION
The Detroit Water and Sewerage Department (DWSD) developed a Greater Detroit Regional Sewer System (GDRSS) model using a modified United States Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) to assist in developing the best approach to reduce combined sewer overflow discharges. The GDRSS collects flows from the City of Detroit and all or part of 76 surrounding communities covering nearly 2,300 square kilometers and serving approximately three million people. The hydrologic model consists of 337 distinct subbasin drainage areas, and the hydraulic model consists of more than 1,400 explicitly modeled conduits with over 140 combined sewer overflow (CSO) locations. The model has been used to predict system response to various storm events under various CSO control alternatives. At the request of the MDEQ, the variability in model results due to uncertainty in parameters' values was evaluated. As part of this evaluation, the impacts of seasonal variation in certain parameters were investigated.

To address this issue, an approach was developed to investigate seasonal varying parameter impacts on continuous model results. The parameters that were investigated included: DWF, evaporation, and RDI/I volume. The seasonal variation was evaluated to determine the impacts on model results relative to annually averaged values of dry weather flow, evaporation and RDI/I volume parameters. Seasonal variation impacts were evaluated for the continuous model using both an annual and a seasonal extreme period (representing a *wetter* period of the year in Detroit, March through May).

Model simulations were performed and the results compared to that of the baseline model. The parameter values were input as either seasonally varying or annually averaged. The extent of the model parameter impacts depends on the model's sensitivity to the given parameter, the degree of difference between annual average values and the seasonally varying values, and the period of the year evaluated.

The results of six model simulations (five continuous and one baseline simulation) were evaluated to quantify discharge to the Detroit collection system from suburban districts as well as overflow occurring before entry into the Detroit system. Within Detroit, the flow to the wastewater treatment plant (WWTP) and upstream overflows were evaluated. All results were compared to the baseline model conditions with a detailed accounting of continuity error impacts. Conclusions are presented in terms of the relative impacts of these parameters relative to the baseline model.

METHODOLOGY

Parameter Selection

The parameters selected for these analyses were based on the experience of GDRSS model users. This experience includes model development, sensitivity analyses, calibration and validation of the continuous and event models. Furthermore, parameters were chosen for which new methodology was developed or for which substantially increased detail was added throughout the project. During the GDRSS project, new methodology was developed for parameter spatial distribution such as RDI/I C factors that vary as a function of sewer construction age. Furthermore, more detail was added to model seasonal variation in DWF. Seasonal variation in evaporation is not a new methodology; however, it was considered to provide a reference to which the other results could be compared.

Dry Weather Flow

DWF was varied using monthly multiplication factors of the base DWF value. The TRANSPORT monthly flow factor parameters were added to the SWMM model by Camp Dresser and McKee (CDM) to facilitate Phase III GDRSS project needs. The DWF factors were developed using a correlation of district (billing regions) flows to WWTP flows for each district. An example of this is shown in Figure 1 for Western Wayne County. Seasonal DWF factors for each region could then be determined for any year, within reason, based on observed flows at the WWTP. For the GDRSS model, these factors are input as monthly values to account for seasonal variation in these flows. Figure 2 shows the flow factors for Western Wayne County. All district factors are listed in Table 1. Different sets of values are used depending on the location within the system as determined from the source data. Areas of the system with large DWF factor variation throughout the year are typical of older, leakier systems. Whereas, regions of the system with minor variation in DWF factors throughout the year are typical of newer systems. To evaluate the impacts of seasonal variability in DWF, the monthly factors were averaged to obtain an annual value for each region.

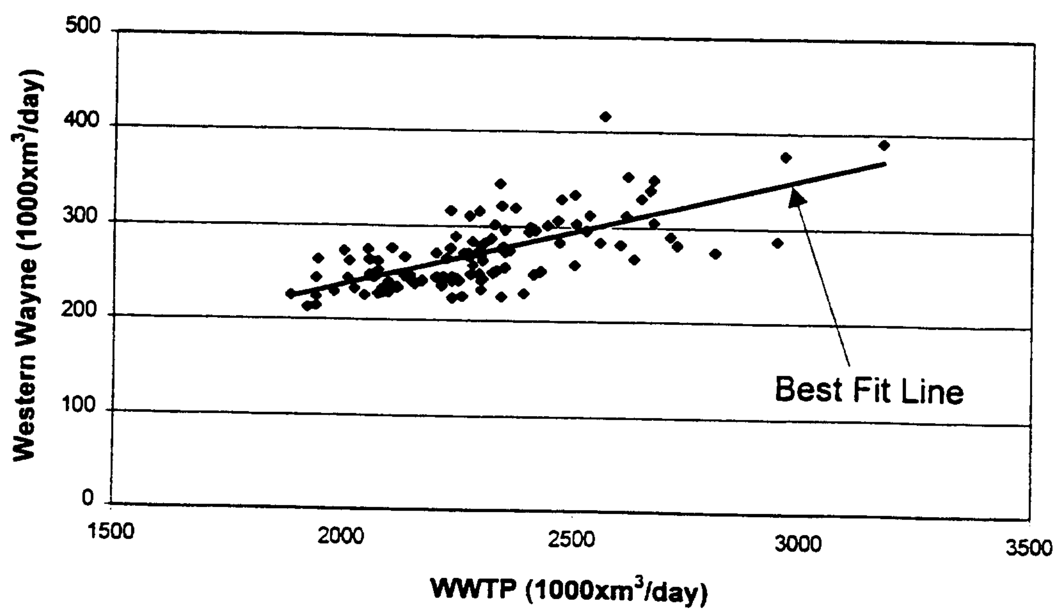

Figure 1 DWF Correlation Plot of Western Wayne to the WWTP

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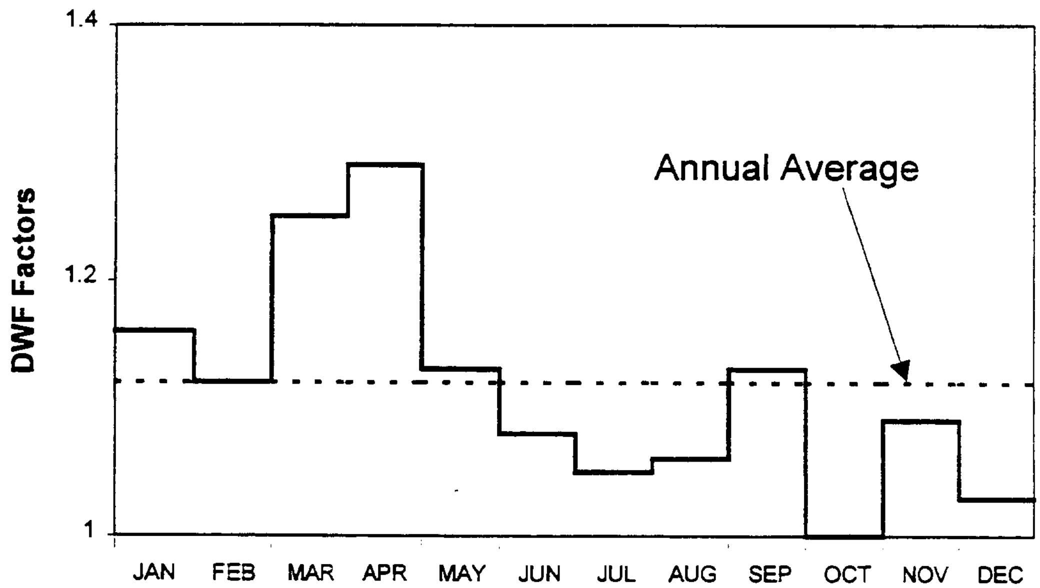


Figure 2 DWF Factors for Western Wayne County

Table 1 DWF Factors by District

District	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Detroit	1.18	1.14	1.29	1.33	1.15	1.09	1.06	1.07	1.15	1.00	1.11	1.04
Allen Park, Melvindale	1.13	1.09	1.20	1.23	1.10	1.06	1.04	1.05	1.10	1.00	1.07	1.03
Centerline	1.16	1.12	1.25	1.28	1.13	1.08	1.05	1.06	1.13	1.00	1.09	1.03
Fox Creek/East Side	1.22	1.16	1.35	1.40	1.18	1.11	1.07	1.08	1.18	1.00	1.13	1.05
Clinton - Oakland	1.03	1.02	1.05	1.06	1.03	1.02	1.01	1.01	1.03	1.00	1.02	1.01
East Dearborn	1.09	1.06	1.14	1.15	1.07	1.04	1.03	1.03	1.07	1.00	1.05	1.02
West Dearborn	1.28	1.21	1.44	1.50	1.23	1.14	1.09	1.11	1.23	1.00	1.16	1.06
Evergreen - Farmington	1.15	1.11	1.23	1.26	1.12	1.07	1.05	1.06	1.12	1.00	1.08	1.03
Farmington	1.25	1.19	1.40	1.46	1.21	1.13	1.08	1.10	1.21	1.00	1.15	1.06
Macomb	1.11	1.08	1.17	1.19	1.09	1.05	1.03	1.04	1.09	1.00	1.06	1.02
Western Wayne	1.16	1.12	1.25	1.29	1.13	1.08	1.05	1.06	1.13	1.00	1.09	1.03
S. E. Oakland	1.16	1.12	1.25	1.29	1.13	1.08	1.05	1.06	1.13	1.00	1.09	1.03

Evaporation

The SWMM RUNOFF block allows monthly evaporation values for input. The evaporation parameter ranges were determined from the relative difference of the local variation obtained from a hydrology textbook (Viessman et al.). The relative difference was applied by month to the model's baseline annual distribution. This yielded the ranges shown in Figure 3. The monthly values were averaged to obtain an annual value. The average value is also shown in Figure 3 as a horizontal line. All values for evaporation were applied globally to the model.

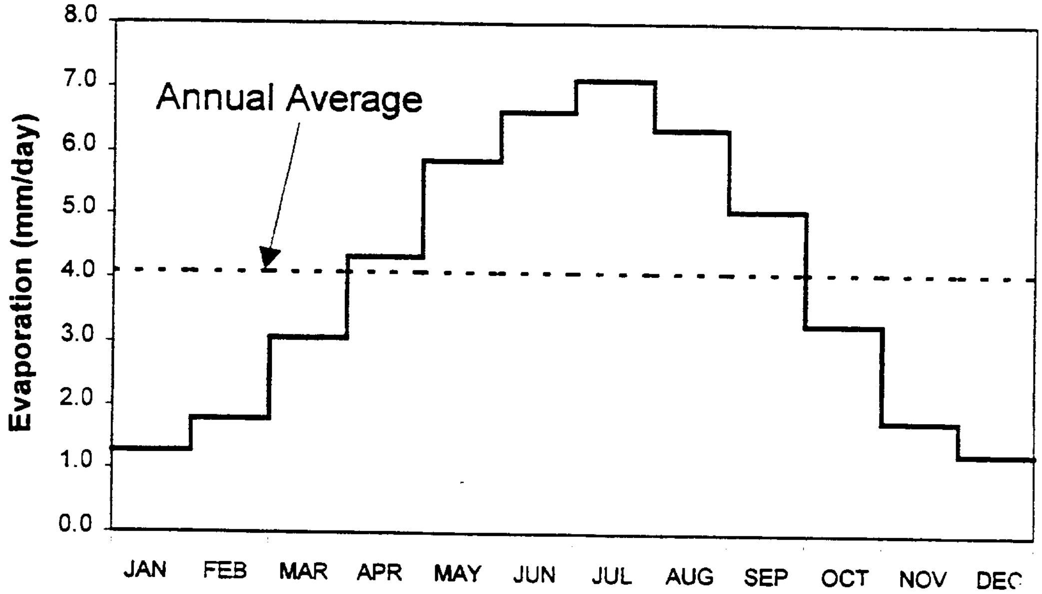


Figure 3 Global Evaporation Parameter

Rainfall Dependent Inflow and Infiltration Volume
RDI/I response volume consists of four parameters. The initial abstraction, V_o, represents the available storage at the beginning of a rainfall event. If the rainfall is below V_o, then no response will occur. However, V_o depends on antecedant moisture and ranges anywhere between zero and the second parameter, maximum V_o. Rainfall causes V_o to reduce and the third RDI/I volume parameter, V_o recovery rate, allows increases in V_o up to the maximum during interevent time periods. When rainfall exceeds V_o, the response volume depends on the fourth parameter, the RDI/I C factor. Each of these parameters is varied seasonally. The V_o parameter is dependent on the maximum V_o and the recovery rate, and is used as model input only in the form of an initial condition.

The model characterization of RDI/I volume is shown in Figure 4. Further information regarding the characterization of RDI/I can be found in the papers by Sherman et al. The four parameters used to characterize RDI/I are varied by season as shown in Figure 5. The bottom chart shown in Figure 5 depicts V_o and maximum V_o as being equal. For initial condition input to the model, V_o was assigned the same value as the maximum V_o. Once the simulation begins, V_o is varied throughout the simulation based on rainfall and interevent recovery. The seasons are defined as *dormant* (December through April), *growth* (June through September) or *transition* (May and November). To address seasonal variability in RDI/I volume, the monthly parameters for maximum initial abstraction, initial storage, recovery rate for storage, and the total response volume originally defined for the dormant, growth, and transition seasons were time weighted averaged to obtain an annual value. The individual parameters were not evaluated independently. That is the four RDI/I volume parameters were aggregated for simulation, either all four parameters treated as seasonally varying or all four parameters treated as annual averages. The seasonal variation in the RDI/I C factors was correlated to housing unit age as a surrogate for sewer construction age and is shown in Figure 6.

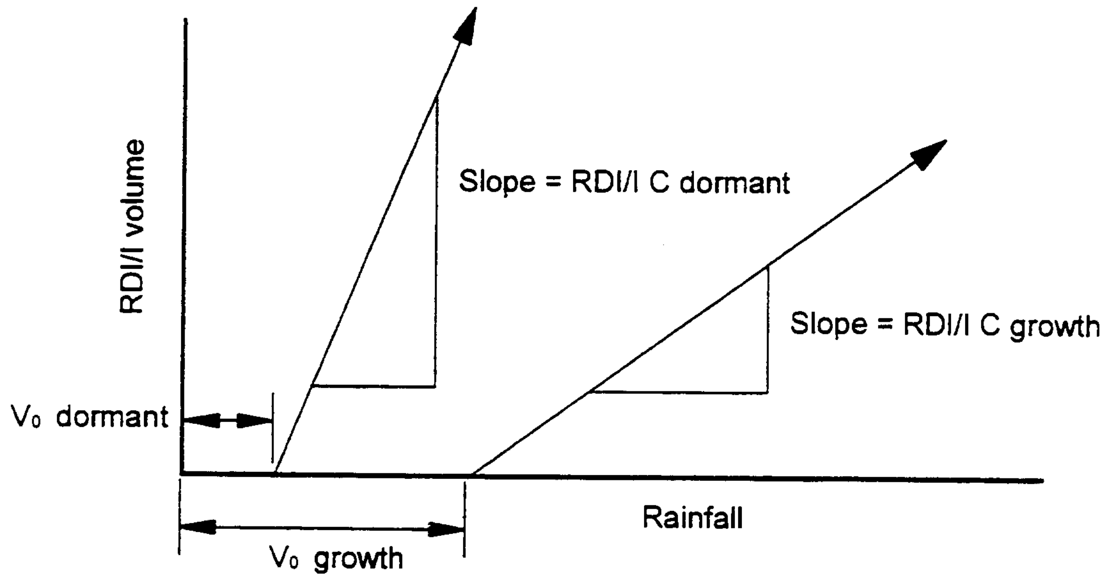


Figure 4 RDI/I Characterization

Accounting of Continuity Error on Results

The EPA SWMM model calculations produce a certain level of continuity error when balancing flows into, out of, and stored in the system. This error is relatively small. However, for simulations in which the seasonal variation impacts are small relative to the baseline simulation, continuity error may be significant. This is because the simulation results may represent either the parameter variation or the differences in the continuity error. This problem is further exacerbated because multiple submodels are used and hydrologic and hydraulic models are coupled i.e., each submodel and each model type had continuity error during the simulations. The use of submodels simplifies debugging and simulation.

An approach was developed to account for the impact of the continuity error on the results. For each RUNOFF submodel, it is assumed that all the continuity error is due to the calculation of RUNOFF outflow volume i.e., assumes all modeled volumes are calculated without error except the RUNOFF outflow. This gives a worst case evaluation of continuity error impact on the resulting objective statistics, *toward treatment* and *to overflow* volumes. This RUNOFF outflow volume is that which is used as input to the TRANSPORT model.

By assuming all continuity error is due to the calculation of RUNOFF outflow, a worst case outflow volume is calculated by setting the continuity equation equal to zero. The worst case classification applies, provided the assumption that the other flow components of the mass balance are calculated without error. This new RUNOFF outflow volume is then substituted into the TRANSPORT continuity equation and a composite continuity error is calculated. A similar approach is used for the continuity error in TRANSPORT outflow points from submodels to the central, downstream-most, submodel. The various submodels' output are combined using the SWMM COMBINE block. It was not necessary to consider the effects of combined submodels on continuity error for districts within a given submodel, except that due to the coupling of RUNOFF with TRANSPORT. In either case, a composite continuity error value was obtained for each district. This composite continuity error was compared to the TRANSPORT continuity errors for each district. From this comparison, the largest magnitude continuity error was used to calculate a modified relative difference as follows in Equation 1:

$$Difference = \frac{V_{sim} \cdot (1 + \varepsilon_{sim}) - V_{base} \cdot (1 + \varepsilon_{base})}{V_{base} \cdot (1 + \varepsilon_{base})} \cdot 100 \qquad (1)$$

Where, V is the output volume and ε is the composite continuity error for the simulation in question and the baseline. The results of Equation 1 and 2 are compared to ascertain the impacts of continuity error on the results. The continuity error has a significant contribution to the change observed in the model response to the perturbation of a parameter if the relative differences calculated using Equations 1 and 2 are markedly different.

$$Difference = \frac{V_{sim} - V_{base}}{V_{base}} \cdot 100 \qquad (2)$$

For every simulation these two equations are evaluated and compared. Results are discussed in a qualitative context and have not been used to *correct* model output for continuity error. The continuity error evaluation results are indicators of potential impacts due to numerical error.

Each submodel simulation had continuity error and it was assumed that the error could be uniformly distributed throughout the submodel. This assumption was used to apply the continuity error to the district level. Furthermore, the City of Detroit district is unique because it spans two submodels of the TRANSPORT simulations. Consequently, the continuity error was weighted by total outflow from each of the submodels before applying to the relative difference calculation. Likewise, for the result totals, the continuity error was weighted for each submodel and applied per Equation 1.

Model Configuration of Precipitation

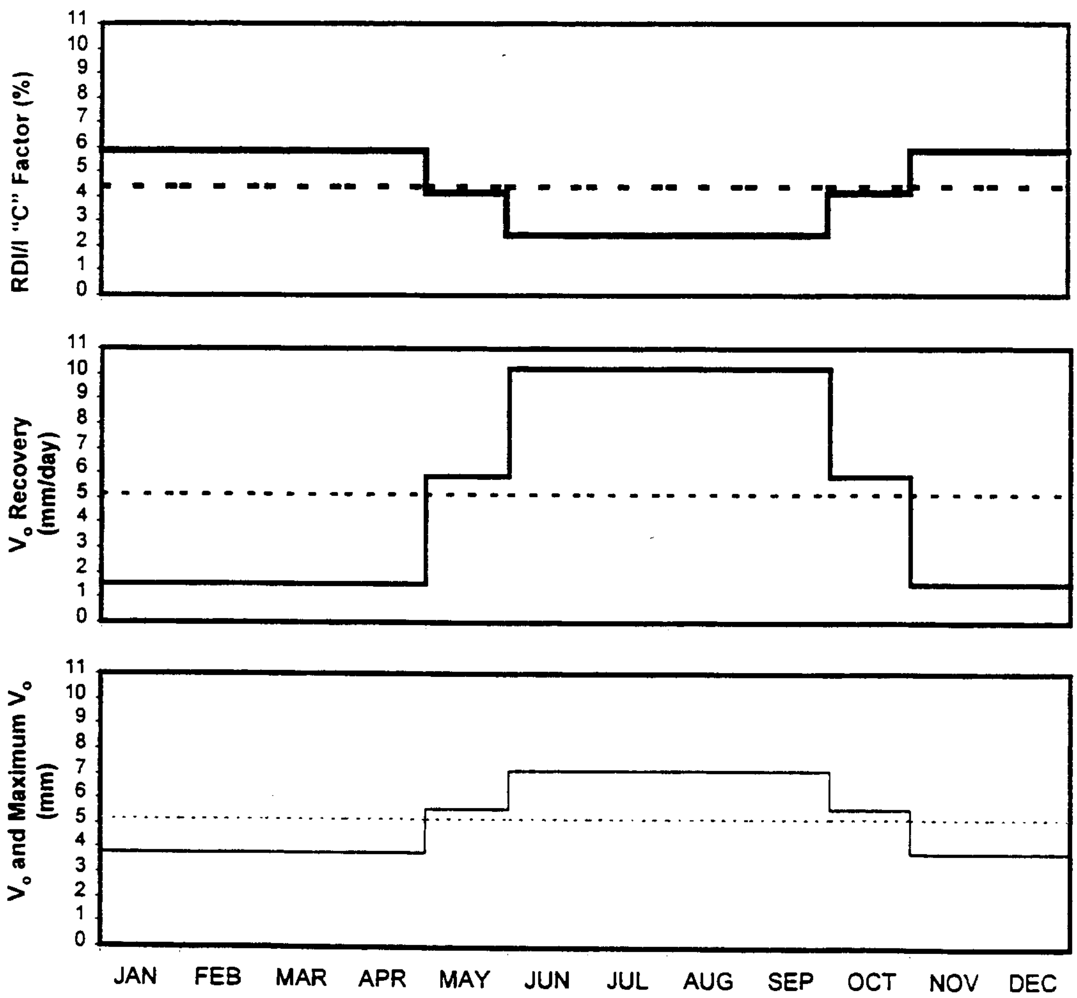
The continuous model (RUNOFF/TRANSPORT) simulations were each evaluated as coupled hydrologic and hydraulic models. A three-year (1984 through 1986) precipitation record was used for all RUNOFF/TRANSPORT simulations. The three-year period was chosen because its data has similar statistics to long-term rainfall averages. The spatial and temporal variation in the rainfall record is assumed uniform throughout the system i.e., no moving front and the same rainfall distribution over all modeled areas. It should be noted that precipitation is a model input that may have significant seasonal impacts on model results, particularly in regions of the country with pronounced rainy seasons, snow accumulation/melt, and year to year changes. The results discussed below could be significantly different if another precipitation record were chosen.

RESULTS

The seasonal variation impacts are discussed in terms of overall model totals and for one of the predominately separate sewered districts, Western Wayne County. It should be noted that the results for other districts that are not discussed and that are either predominately separate or combined sewers will differ significantly from these system-wide results. The system is comprised of approximately 75 percent separate and 25 percent combined sewers. Slightly more than half of the dry weather flow originates from the combined sewer areas. RDI/I is not modeled in the combined sewer areas of the system since the directly connected impervious area runoff dominates any RDI/I components observed for these regions. Therefore, when reviewing the results for the entire system, it is clear that RDI/I yields relatively small impacts. And, when reviewing the results for the separate sewer regions of the system, RDI/I yields significant impacts.

The seasonal variation impacts primarily yield insight to the significance of modeling these parameters seasonally versus modeling these parameters as average annual values. Seasonal variation results for the continuous simulations were expected to have little difference on an annual basis. Consequently, the continuous model was also evaluated for a three-month period (March - May, 1984). This period was considered a seasonal extreme for two of the three parameters. Evaporation was not at the extreme during this period, but was slightly above its annual average as shown in Figure 3. Therefore, a second seasonal extreme period was selected (November 1984 through January 1985) that corresponded to the seasonal extreme for evaporation. The seasonal extreme for each parameter is considered as the period with the *wettest* response. This is because the overall modeling project is focused on overflows, with peak flows being the most important. One could, however, also evaluate the opposite or *driest* response extreme.

Table 2 summarizes all RUNOFF/TRANSPORT seasonal variation impacts for the three-year continuous simulation and a three-month subset. The three-year simulations yielded similar results regardless of whether seasonal variation or average annual values are used. Since there tends to be a predominance of larger or higher intensity storms during the three-month seasonal extreme period the annual results do exhibit a slight reduction in flows *toward treatment* and *to overflow* when annual averages are in place, with the exception of evaporation discussed below. This observation was expected for annual distribution of rainfall for this three-year period.



Solid lines are seasonal
Dashed lines are annual averages

Figure 5 RDI/I Volume Parameters – Seasonal Variation

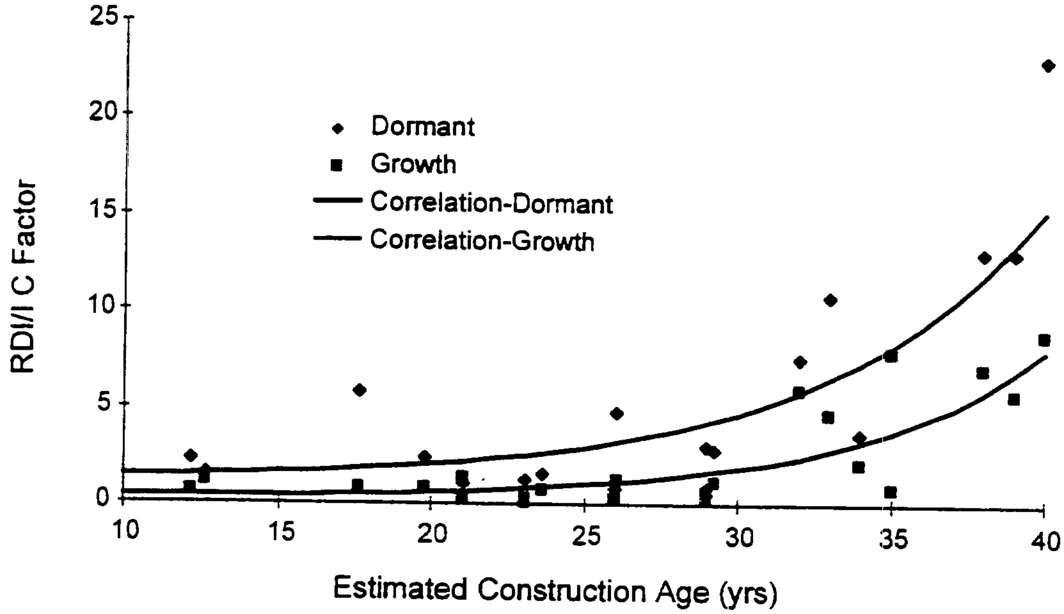


Figure 6 RDI/I C Factor Correlation Surrogate for Construction Age

Table 2 Seasonal Variation Impacts Continuous Simulation Results - Entire System

Simulation ID	Result Type	Baseline 1,000x(m^3/yr)	Annual Avg. 1,000x(m^3/yr)	Relative Difference (%)	Baseline 1,000x(m^3/yr)	Extreme 1,000x(m^3/yr)	Relative Difference (%)
Non Seasonal all as Avg. Annual	Toward Treatment	996,019	990,213	-0.6	90,773	83,273	-8.3
	To Overflow	72,890	72,508	-0.5	4,895	4,619	-5.6
Dry Weather Flow as Avg. Annual	Toward Treatment	996,019	995,501	-0.1	90,773	83,787	-7.7
	To Overflow	72,890	72,825	-0.1	4,895	4,714	-3.7
RDI/I Volume as Avg. Annual	Toward Treatment	996,019	994,480	-0.2	90,773	90,202	-0.6
	To Overflow	72,890	72,965	0.1	4,895	4,835	-1.2
Evaporation as Avg. Annual	Toward Treatment	996,019	992,375	-0.4	90,773	90,833	0.1
	To Overflow	72.890	72,436	-0.6	4,895	4,854	-0.8

The results in Table 2 indicate that the DWF seasonal representation is quite significant during the seasonal extreme period. The seasonal variation in the RDI/I representation yields significantly less impact. Although still dominated by DWF, the districts with primarily separate sewers yielded a significantly greater impact from RDI/I. See Table 3 for results for Western Wayne County, a predominately separately sewered district.

The RDI/I results are important. Without having performed the parameter analyses regarding the seasonal variation of RDI/I, incorrect annual average values would have been obtained in most cases for these parameters. For example, if one assumed that RDI/I parameters could be obtained from data collected during the summer months and used as a single annual average value in the model, the model would grossly underpredict the dormant season flows. The importance of correctly defining annual average RDI/I parameters cannot be overemphasized. Since many modelers will not go through the detailed model characterization as done herein for the seasonal variation in RDI/I, an appropriate annual average must be used to account for the seasonal variation on the annual basis. Regardless of whether or not a reasonable annual average is chosen, one who uses the annual averaged values will still run the risk of inaccurately predicting flows for seasonal extreme periods relative to the average.

Table 3 Seasonal Variation Impacts Results for Western Wayne County (Predominately Separate)

Simulation ID	Result Type	Baseline 1,000x(m^3/yr)	Annual Avg. 1,000x(m^3/yr)	Relative Difference (%)	Baseline 1,000x(m^3/yr)	Extreme 1,000x(m^3/yr)	Relative Difference (%)
Non Seasonal	Toward Treatment	29,140	29,060	-0.3	2,706	2,430	-10.2
all as Avg. Annual	To Overflow	892	885	-0.8	62	59	-4.8
Dry Weather Flow	Toward Treatment	29,140	29,239	0.3	2,706	2,492	-7.9
as Avg. Annual	To Overflow	892	892	0.0	62	61	-1.6
RDI/I Volume	Toward Treatment	29,140	28,987	-0.5	2,706	2,645	-2.3
as Avg. Annual	To Overflow	892	892	0.0	62	60	-3.2
Evaporation	Toward Treatment	29,140	29,117	-0.1	2,706	2,706	0.0
as Avg. Annual	To Overflow	892	884	-0.9	62	62	0.0

The seasonal extreme period evaporation values were slightly above the annual average; consequently, the evaporation only simulation yields even greater difference than when all seasonal variation is converted to annual averages. Evaporation was evaluated at the seasonal extreme for DWF and RDI/I as shown in Tables 2 and 3. However, this period is not the seasonal extreme for evaporation. The seasonal extreme for evaporation is the November to February period, as shown in Figure 3. This time period is a seasonal extreme because lower evaporation can contribute to greater system responses. The evaporation only simulation and the baseline were reanalyzed for a seasonal extreme more relevant to evaporation impacts, November 1984 through January 1985. Table 4 shows the results of this additional analysis, and indicates significant impacts for evaporation during this seasonal extreme.

Table 4 Evaporation Re-evaluated (Nov. – Jan. Extreme)

Simulation ID	Result Type	Baseline 1,000x(m^3/yr)	Annual Avg. 1,000x(m^3/yr)	Relative Difference (%)	Baseline 1,000x(m^3/yr)	Extreme 1,000x(m^3/yr)	Relative Difference (%)
Evaporation	Toward Treatment	996,019	992,375	-0.4	82,506	81,372	-1.4
as Avg. Annual	To Overflow	72,890	72,436	-0.6	2,650	2,563	-3.3

The continuity error influence was negligible for all the RUNOFF/TRANSPORT seasonal variation impacts simulation results. That is Equations 1 and 2 produced the same value. This is not always the case in modeling; therefore, it is important to mention only to show that there are no expected impacts due to continuity error. The three-month seasonal extreme period results were extracted from the three-year continuous simulation results; therefore, continuity error checks during that period may not be representative although assumed accurate. Even though the observed change is minimal between the relative difference calculations, the period considered for the continuity error may be important. Improved confidence in the continuity error impact estimates would be possible if additional simulations for the three-month period were performed; however, additional simulations were not warranted.

DISCUSSION

The results give some insight into model sensitivity to seasonal variation in parameter values. However, some other EPA SWMM seasonally varying parameters were not included in the analysis. For example, these analyses did not include parameters such as precipitation, temperature, snow melt, or RDI/I shape. RDI/I shape parameters define the response hydrograph shape by three component hydrographs, an early direct response (inflow), an intermediate response, and a delayed response (infiltration). For Southeastern Michigan, the seasonal variation in precipitation was not expected to be significant; however, for other systems for which a *rainy* season is more pronounced, seasonal variation in precipitation is likely to yield significant impacts since precipitation is the parameter for which RUNOFF is most sensitive.

Furthermore, a simplification was made when aggregating the parameters included in the characterization of RDI/I volume. These four RDI/I volume parameters were aggregated and not evaluated individually. If each aggregated parameter was evaluated individually, more insight would be gained as to which of the four parameters were of the greatest importance to accurately quantify if the modeler chooses to use annual average values instead. Of the RDI/I volume parameters, the most important parameter to quantify for the GDRSS was the RDI/I C factor. RDI/I volume parameter importance was evaluated through continuous simulation sensitivity analysis by Sherman et al. (1998).

CONCLUSIONS

This work represents an effort to provide a basis for the users of the model to understand how seasonal variation impacts model results. The seasonal variation versus annual average values for DWF, RDI/I volume, and evaporation were considered. From these results, DWF produces the greatest impacts due to seasonal variation throughout the system. RDI/I produced small impacts to the entire system; however, for predominately separate sewer districts the RDI/I yielded significant impacts. The seasonal extreme for evaporation did not occur during the same period as for DWF and RDI/I. Therefore, another period was considered between the months of November and January to better understand the seasonal variation impacts due to the evaporation parameter. Evaporation did exhibit a significant impact during the second seasonal extreme period chosen when compared to the annual average.

The most important conclusion is that when any seasonally varying parameter is modeled as annually averaged values, the data used to generate the average value must account for seasonal variation. Figures 2, 3, and 5 can be used in conjunction with the results to support this claim. For example, if July through December data were used to estimate DWF as shown in Figure 2, the value used as an annual average would be significantly lower than that determined using a full 12 months of data. The seasonal extreme impact during March through May would then be far more significant than that elucidated by the simulations herein. As a result, it is important to base annual averages on an appropriate weighting of data spanning the entire year. If limited data is available for single periods, such as growth or dormant periods, an attempt should be made to make estimates of annual performance values and apply these for long-term simulations. For simulations less than one year, the parameter values chosen should represent the seasons evaluated using either seasonally varying values or an appropriately derived average for the period in question.

ACKNOWLEDGMENTS

The Greater Detroit Regional Sewerage System model development is being conducted by the Detroit Water and Sewerage Department (DWSD). We are grateful to David A. White, P.E., of Wade-Trim Associates for assisting with post-processing.

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DEVELOPMENT OF A COMPLEX INTEGRATED MODEL OF THE BATON ROUGE CITY/PARISH PRESSURIZED AND GRAVITY WASTEWATER COLLECTION SYSTEM

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ABSTRACT

The City/Parish of Baton Rouge operates a highly complex wastewater collection system that includes a combination of gravity sewers, lift stations, and a very large manifold force main system with in-line booster pumps. In September of 1995, the City/Parish embarked on a comprehensive SSO Corrective Action Plan (SSO CAP) that required an analysis of the wastewater collection system, including the assessment of I/I impacts and the requirements to accommodate future growth. In order to achieve the objectives outlined in the SSO CAP, it was necessary to construct detailed hydraulic models of the collection system that could accurately simulate the dynamics of wet weather impacts and could be used to assess and design cost effective overflow control measures.

Due to the nature and complexity of the collection system, it was necessary to develop a model that is highly robust and can handle both long pressure force main and gravity sewer hydraulics simultaneously, as well as incorporate the real time control mechanisms currently used to operate the in-line booster stations on the pressurized system.

This paper details the steps taken to construct the calibrated model of the South Suburban Transport Network (STN) sewerage system which integrates the large manifolded pressurized trunk system with the gravity collector pipe network. This paper discusses the development of this model, including the data management and GIS system, model calibration, observations and discoveries made during the modeling process and finally application for the model to develop cost-effective improvement schemes for the Baton Rouge City/Parish.

KEYWORDS

hydraulic modeling, real time control (RTC), pressurized sewer modeling, sewer, hydraulic, hydrologic, model calibration, booster stations

INTRODUCTION

Baton Rouge is the capital of Louisiana with a population nearing 400,000 people and is situated along the east bank of the Mississippi River in southern Louisiana. The land generally falls gently away from the river with a difference in elevation of less than 16m (50ft) between the 5 and 95 percentile manhole. The Baton Rouge sewerage collection system consists of over 36,000 manholes, approximately 2516 km (1564 miles) of gravity sewer, over 400 pumping stations, two major pressurized collection systems containing approximately 307 km (191 miles) of forced mains and three major waste water treatment facilities which discharge to the

Mississippi. Due to rapid growth in development and excessive levels of inflow and infiltration, parts of the system have reached full design capacity 10 years ahead of expectation.

In September of 1995, Phase 1 of the Baton Rouge City/Parish (C/P) SSO Corrective Action Plan was initiated. The objective of this effort was to develop a detailed strategy and scope for a system-wide sewerage master plan that addresses both future growth and the reduction of SSO's. The result of this effort was a strategy for a Phase 2 effort that focused on the detailed analysis of the complex wastewater collection system using sophisticated hydrologic/hydraulic models.

For the Phase 2 effort the collection system has been divided into five discrete catchment models. Three of these catchments consist primarily of older gravity sewers and common lift stations. The other two catchments are comprised of multiple discrete gravity systems that pump into two complex manifolded force main systems, referred to herein as the Suburban Transportation Networks (STN), North and South.

Many other municipalities that operate similar pressurized trunk sewer systems, particularly in the South East United States, have grappled with how to best analyze these complex type of system. This paper will focus on the analysis of the South STN system, discuss in detail how this system has been modeled and analyzed using a state of the art computer model and describe the benefits that this type of tool can provide to a collection system manager. It is intended that this paper will serve as a guideline for wastewater collection managers as to the steps required to develop such a tool and provide an insight into the technology currently available in this field.

BACKGROUND TO SOUTH STN SYSTEM

The South STN sewer system serves the rapidly developing south-east of Baton Rouge and consists of relatively small catchments of 20 to 200 hectares (50 to 500 acres) which drain by gravity pipes and 20 gravity lift stations into 90 pumping stations which inject directly into a manifolded pressurized trunk system. Figure 1 illustrates the extent of the modeled pipe network for the South STN model. Flows within the pressurized trunk system are conveyed to the treatment works via 7 major in-line booster pumping stations and 2 mini-booster stations. Average daily dry weather flows at the South treatment works from the STN are in the order of 0.43 m^3/s (10 MGD) with recorded peak wet weather flows in excess of 2.63 m^3/s (60 MGD).

The in-line booster stations are designed to activate when flows exceed 30% of peak capacity and the pressure in the force main at the booster exceeds a predetermined set point. The objective of each booster station when operating is to maintain a steady pressure on the suction side of the pumping station. During periods of high flow the booster pumps are controlled with variable speed drives to fix the pressure on the suction side which enables the injection pumping stations upstream of the booster to discharge into the system.

Static KY-Pipe models of the trunk system have been historically used to analyze the effect of additional peak flows from proposed developments connecting into the STN system. These models are however unable to simulate the complex dynamic interaction between the gravity sewers, injection pumping stations and booster pumping stations. Furthermore, these static models do not allow analysis of potential optimization schemes that could significantly improve system performance and reduce operation costs.

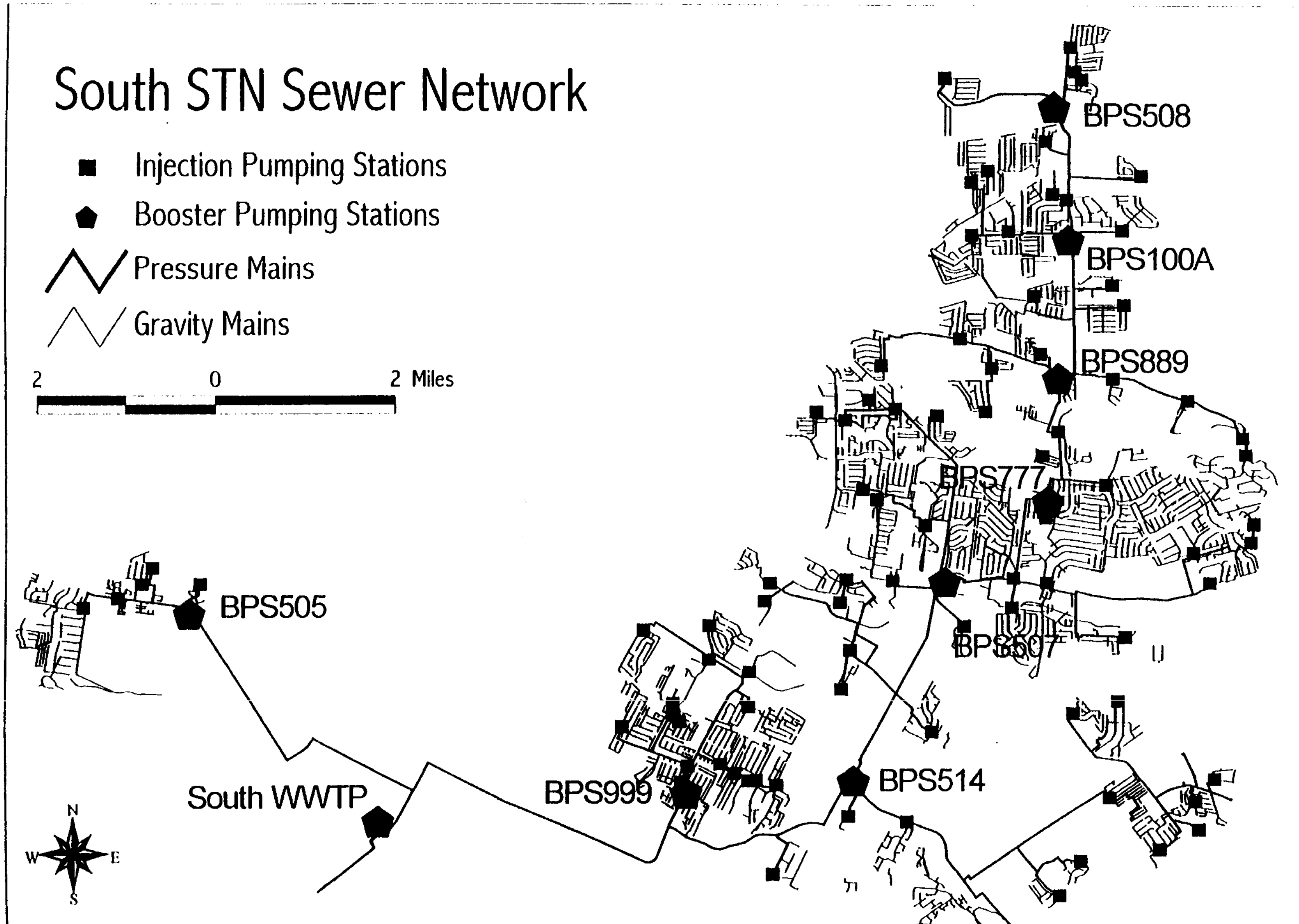

Fig. 1

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MODEL DEVELOPMENT

The following provides a summary of the key tasks undertaken during the development of the South STN model:

- A physical inspection and survey program of approximately 700 manholes (out of 5,000 manholes system wide) which included all pipes 250mm (10 in.) in diameter and larger as well as selected 200mm (8 in.) pipes in critical locations such as known SSO's or where there is a potential hydraulic throttle.
- Development of a state of the art GIS / data management system capable of storing all sewer and catchment attribute information, producing model input files and processing and displaying results.
- Sub-basin delineation and geoprocessing within the GIS to distribute Census data, water usage data and land use information to the modeled sub-basins.
- Physical inspection and pump testing of major gravity lift stations to construct "actual" pump curves for use in the model.
- Collation of physical attribute data for the pumping stations, booster pumping stations and force mains in the STN systems from "as built" records and input into the GIS.
- Collation of pump curves for each STN pumping station and determination of booster station operation rationale from O&M manuals, discussions with operators and system designers, observations during wet weather, development of real time control (RTC) logic to mimic booster pumping station operation and input of data into the GIS.
- Simplification of the model within the GIS by aggregating pipes of the same size and hydraulic characteristics.

The final model contains;

- 7 in-line booster stations,
- 7 RTC actuated sluice gates,
- 20 lift stations,
- 90 pumping stations injecting into the manifolded force main network,
- a manifolded pressurized network containing 243 pipes, and
- 522 gravity pipes ranging from 200mm (8 inches) to 450mm (18 inches)

The modeling software selected for this project was HydroWorks™ V2.2 as it was the only commercially available dynamic modeling software capable of dealing with pressurized pipes and the real time control (RTC) functionality necessary to model the booster pumping stations.

MODEL CALIBRATION

The models were calibrated with data from the following sources:

- Flow monitoring and rainfall data from a comprehensive 60 day temporary flow monitoring survey of the gravity sewers conducted from August to October 1996.
- Flow records from the influent meter at the treatment works.
- Weekly chart records of flow rates and pressures from the 7 booster pumping stations.

A challenging aspect of the model calibration effort was the development of RTC logic to mimic the complex operation rationale of the booster pumping stations in the STN system. Each station has either 2 or 3 variable speed pumps whose operation and speed is governed by a series of algorithms with inputs from the pressure sensors located upstream and downstream of the booster stations as well as the flow rate recorded by in-line flow meters downstream of each booster.

The models were first calibrated to accurately simulate the weekday and weekend diurnal dry weather flow patterns using an integrated facility within the HydroWorks™ modeling software called the "Waste Water Generator" (WWG). Model files produced from the GIS included residential and equivalent commercial populations, diurnal profile indices and ground water infiltration. When conducting simulations the WWG used this information to develop dry weather inflows "on the fly". Key advantages of developing dry weather flows using this tool include:

- Differentiation between sanitary flows and ground water infiltration.
- An internal clock which references the actual dates and times of the simulation event. By this means the appropriate weekday or weekend diurnal dry weather profile is automatically applied to a simulation trial.
- The model is constructed such that it can be readily migrated for use in Water Quality simulations in the future.
- Using the GIS to store attribute and catchment information facilitates an effective audit trail and efficient model updating for assessing the effects of future development.

Following dry weather calibration the model was calibrated against a range of recorded wet weather events. Wet weather calibration was achieved using a run-off and routing algorithm within the model well suited for the simulation of I/I response characteristics. Interesting aspects of the wet weather calibration process undertaken include:

- The model calculated pump rate for each injection pump station was constantly updated depending upon the level in the wet well and the HGL in the pressurized system.
- The process for producing wet weather response hydrographs is internal to the model as opposed to the traditional method applied in the U.S. where the wet weather hydrographs are generated external to the model.
- The sewerage system and topography of Baton Rouge is particularly flat and susceptible to high levels of surcharge during wet weather. Routines were developed to calculate and apply the additional surcharge storage volume available from the unmodeled pipes and manholes and applied to the modeled manholes.
- During calibration the model results were compared to both the recorded flow and depth to enable differentiation between hydrologic processes and the hydraulic attenuation of flows.
- During the flow monitoring survey a selection of storms were recorded ranging from short intense bursts of just over an hour duration to soaking rains of over 2 days duration and 2 year return period. With the model's integrated hydrologic and hydraulic routines it was possible to calibrate the model to adequately simulate both flow and surcharge depth for both extreme events involving extensive surcharge as well for lesser storm events.
- The model was able to simulate the complex interdependency between the booster pumping station operation in the STN trunk system, the pumping rate delivered by the smaller injection pumping stations and the surcharge levels in the gravity components of the STN.

APPLICATION OF THE CALIBRATED MODEL

The calibrated model can now be readily used to simulate individual storms, a batch of historical storms or conduct long term rainfall simulations. Providing the rainfall file has a start date and time, the model will automatically synchronize and apply the appropriate diurnal dry weather flows for the duration of the simulation as well as the calculated wet weather flows to the model. With this high level of functionality the model can be readily used for the following:

- Optimization of system operation by batch simulating a storm series, analyzing the results to identify any non-optimal practices, developing and simulating revised operational sequences.
- Identifying and simulating the application of proposed SCADA control systems to maximize the utilization of existing in-system surcharge storage.
- Analyzing the effect of future development on the whole of the inter-dependent system to assess optimal augmentation strategies.
- Identifying the cause of flooding from historical rainfall events.
- Analyzing the long term cost benefit of I/I mitigation works versus transfer system augmentation, installation of storage facilities and or treatment plant upgrade.

DISCUSSION

The Baton Rouge south STN model is possibly the largest hybrid pressure / gravity sewer model constructed to date. As the pressurized pipe solution is a relatively new feature in HydroWorks™ a number of "traps for young players" were encountered along the way before coming up with the final model solution. Prior to embarking on a similar modeling effort it is advisable that modelers first become familiar with the nuances of such systems, both in the field and from a modeling viewpoint.

Due to the complexity of the system, calculations required to come up with a stable solution during a simulation tend to require a fairly short time step. A 48 hour dry weather simulation on a Pentium 266–64Mb RAM computer took approximately 6.5 hours. The positive aspect is that major wet weather simulations run for 32 hours on the same computer take approximately 4.5 hours. Thus there is no noticeable time penalty due to heavy surcharge in the gravity pipe system during wet weather events.

As a by-product of the investigative process undertaken from data collection through to model calibration and storm analysis, a number of system characteristics have become evident which were not readily identified from the traditional static analysis. The following examples illustrate some of the observations made to date:

- *Inefficient Dry Weather Pump Operation* - during dry weather operation, which accounts for 90-95% of the run time for each pump, many of the injection pumps, sized primarily for peak wet weather, operate a long way out on their curves. This results in inefficient operation for most of their run hours and in some cases indicates the onset of cavitation and high impeller wear due to low net positive suction head (NPSH).

- *Erratic Booster Station Operation* - during the early stages of modeling a great deal of difficulty was encountered when trying to mimic the speed control algorithm for the booster pumps using RTC logic. With flows near maximum capacity the modeled booster pumps performed in a reasonable manner, however when flows were lower the modeled pumps would behave in a manner which appeared to indicate instability. Subsequent site investigations revealed that the booster pumps did in fact continually speed up and slow down following milder storms in accord with the logic programmed into the PLC controllers. A revised logic was tested on the model to stabilize booster operation and has successfully been installed at 4 of the booster stations and is soon to be installed in the remaining sites.

- *Identification of Cavitation Conditions* - since its commissioning in the early 1990's, booster station 514 had suffered from problematic operation in near all conditions other than dry weather or extreme wet weather. Due to excessive vibration, the impellers from two out of the three pumps at the station had worn loose and were out of action for some months while repairs took place. As this booster station pumps directly to the treatment works the discharge pressure or back pressure on the pumps is directly related to the amount of flow through the station. Through the review of model simulations it became apparent that the differential pressure across the pump station was insufficient for the pumps to remain on their curves at medium to low flows and hence cavitation through insufficient NPSH was the likely source of the vibration. A reasonably successful temporary solution has been to partially close the gate valves downstream of each pump to increase the backpressure.

- *Pumps Exceeding Design Flows* – the static model used to design the injection pumping stations assumed that the water level in the wet well remained at the pump switch on level and conservative friction factors to make allowance for future pipe deterioration. In many of the pumping station basins the peak wet weather flows exceed the pump capacity. As a result the water level in the wet well can rise up to 12 ft above the pump switch on level thus reducing the static head to pump against. Combined with the less than estimated pipe friction loss (from relatively new pipe) this has resulted in some pumps operating further out on their curves than designed and in some cases pumping up to 50% above their design capacity. The down side is that within each "cell" of the system, as defined by an upstream and downstream booster station, there is a finite rate of flow which can be injected into the system. For each pump exceeding its design capacity there is another pump which is restricted from injecting into the trunk system.

CONCLUSIONS

The development of an integrated gravity and pressurized pipe model provides waste water system managers and engineers with a powerful tool to analyze and manage these complex sewer systems. Key features of the Baton Rouge South STN model are:

- A powerful GIS-data management system, which can readily produce model, input files.
- The model is capable of simulating the hydraulics in both gravity sewers and long pressurized force mains.
- The model includes all pipes 10 inches and larger (with some 8 inch sewer included in chronic flooding areas), and includes an allowance for the unmodeled storage to enable differentiation between hydrologic and hydraulic effects in the calibrated model. The inclusion of the unmodeled system storage has been found to be critical in terms of successful calibration efforts.
- By calibrating the model with both surcharge and non-surcharge storm events a greater level of confidence can be attributed to simulation results.
- The ability to simulate the wet weather I/I response to rainfall internal to the model lends to the efficient simulation of multiple storm events with different scenarios.

A robust integrated hydraulic model combining both the gravity and pressurized components of a manifolded sewerage system is a powerful tool to achieve the holistic level of understanding necessary for the operation and optimization of such interdependent systems.

COMBINED SEWER SYSTEM: TO SEPARATE...OR...NOT TO SEPARATE

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ABSTRACT

The City of Columbus, OH has implemented the minimum control of maximizing collection system storage as part of the Combined Sewer System Operational Plan. Due to the successful implementation of the storage procedure as designed and the current water quality of the receiving streams, no Long Term Control Plan programs or facilities are required. However, the City is planning to implement previously recommended separation projects to increase collection system capacity. The Chestnut Street Regulator Relief Project was one recommendation which urged separation of a large storm sewer from the combined system.

Concurrently, the City developed a program (Columbus Sewer Capacity Study) to study the hydraulic performance of its sanitary and combined sewerage systems in a comprehensive approach. One purpose of the study is to increase the City's knowledge of real time system hydraulics using modeling techniques and to provide tools to assess system capacity alternatives. Preliminary investigations of the Chestnut Street Regulator project indicate implementing system separation may not reduce the number and duration of overflows from the combined system. This separation project may have a negative impact on the receiving stream and the main intercepting sewer due to the time of concentration change effect on peak flows, and the potential increase in the hydraulic grade line of the combined interceptor.

This paper describes the analysis of a combined sewer system separation project in a global and local approach. It provides insight to the feasibility of utilizing current modeling techniques to offset the expense of a rigorous water quality sampling effort. Results may significantly reduce capital expenditures.

Keywords: Sewer system management, modeling, computer applications, database, wastewater, Permanent Flow Monitors, CSOs

INTRODUCTION

The City of Columbus, Ohio has implemented the minimum control of maximizing collection system storage as part of the Combined Sewer System Operational Plan. Due to the successful implementation of the storage procedure as designed and the current water quality of the receiving streams, no Long Term Control Plan programs or facilities are required. However, the City is planning to implement previously recommended separation projects to increase collection system capacity. The Chestnut Street Regulator Relief Project is one recommendation which urged separation of a large storm sewer from the combined system.

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BACKGROUND

The city of Columbus, Division of Sewerage and Drainage services a total area of approximately 100,000 acres (40,470 hectare) and designs its facilities for ultimate service area of 564 square miles (1,460 square kilometer). The current (1996) service area includes 5,286 acres (2,139 hectare) of combined sewerage drainage, which represents 5.2% of the current service area. There are approximately 2,016 miles (1,957 km) of sanitary sewers, 1,216 miles (1,957 km) of storm sewer, and 202 miles (325 km) of combined sewers within the service area. Of these sewers, approximately 550 miles (885 km) are major interceptors. There are two wastewater treatment plants (WWTP) with total capacity of 150 million gallons a day (mgd) (6.57 m^3/sec) during dry weather flow (DWF) and 252 mgd (11.03 m^3/sec) during wet weather. In addition, the city operates two primary treatment facilities for wet weather flow. The Whittier Street Storm Tanks (WSST), which were built in Columbus in 1932, are the first combined sewage holding facility built in the United States.

During the mid-1980s, the Division of Sewerage and Drainage (DOSD) determined that knowledge of the operations and flow patterns within the main interceptor system was lacking. The Division raised concerns regarding the physical condition of the system and the adequacy of the hydraulic capacity of the interceptors and trunk sewer segments. A program was developed to increase the city's knowledge of the characteristics of the interceptor system and to provide the tools with which to study possible changes to the system.

The program included the development of a collection system hydraulic model based upon an accurately developed sewer system physical description and calibrated against observed field flow data at key locations. The DOSD uses the model to accurately establish pertinent variables and to conduct statistical analysis for assistance in the decision making process.

Objectives of the program, now known as the "Columbus Sewer Capacity Study", include the following: understanding the sanitary and combined sewer system performance under various flow conditions; identifying the need for additional interceptor sewers; investigating the impact of, and possible solutions for identified problems, zoning variations, and/or development; and to establish the best method to control and manage the combined sewer system (CSS).

In 1989, the city of Columbus undertook a Combined Sewer Overflow (CSO) Study to determine the extent of the pollutant load in the receiving stream caused by combined sewer overflows. One finding of the study was suppressed aquatic life in the Scioto River between the WSST discharge point and the Jackson Pike WWTP (JPWWTP) outfall. The suppressed aquatic life in the Scioto River is attributed largely to the frequent activation of the WSST discharge.

Recommendations of the CSO Study included elimination of the storm discharge from a 108-inch (2700 mm) diameter sewer to the Olentangy Scioto Interceptor Sewer (OSIS), which is the primary interceptor to the JPWWTP. This connection is just upstream of the Chestnut Street Regulator. As shown in Figure 1, the existing system also has a 72-inch (1800 mm) diameter pipe from the 108-inch (2700 mm) diameter into the regulator. The tributary area to this 108-inch (2700 mm) diameter pipe includes highway drainage from Interstate 71 (I-71), Interstate 670 and from their interchange area. The Chestnut Street Regulator also has a 117-inch (2925 mm) diameter combined sewer discharging to it which also carries storm runoff from I-71. The CSO Study recommended that this separate storm sewer from I-71 be diverted to the 108-inch (2700 mm) pipe and then separated from the remaining flow to the regulator.

The CSO Study also recommended that the effluent from JPWWTP be diverted to the vicinity of the WSST outfall during low flow periods to provide dilution (with high quality effluent) for CSO discharges and storm water discharges in this stream section. These recommendations were made as a means of reducing CSOs from the WSST and to reduce the impacts to aquatic life in this river segment.

The DOSD did not immediately proceed with the Chestnut Street Regulator separation work due to other higher priority projects. In addition, the Division put all separation projects on hold due to uncertainties associated with the City's Stormwater NPDES permit.

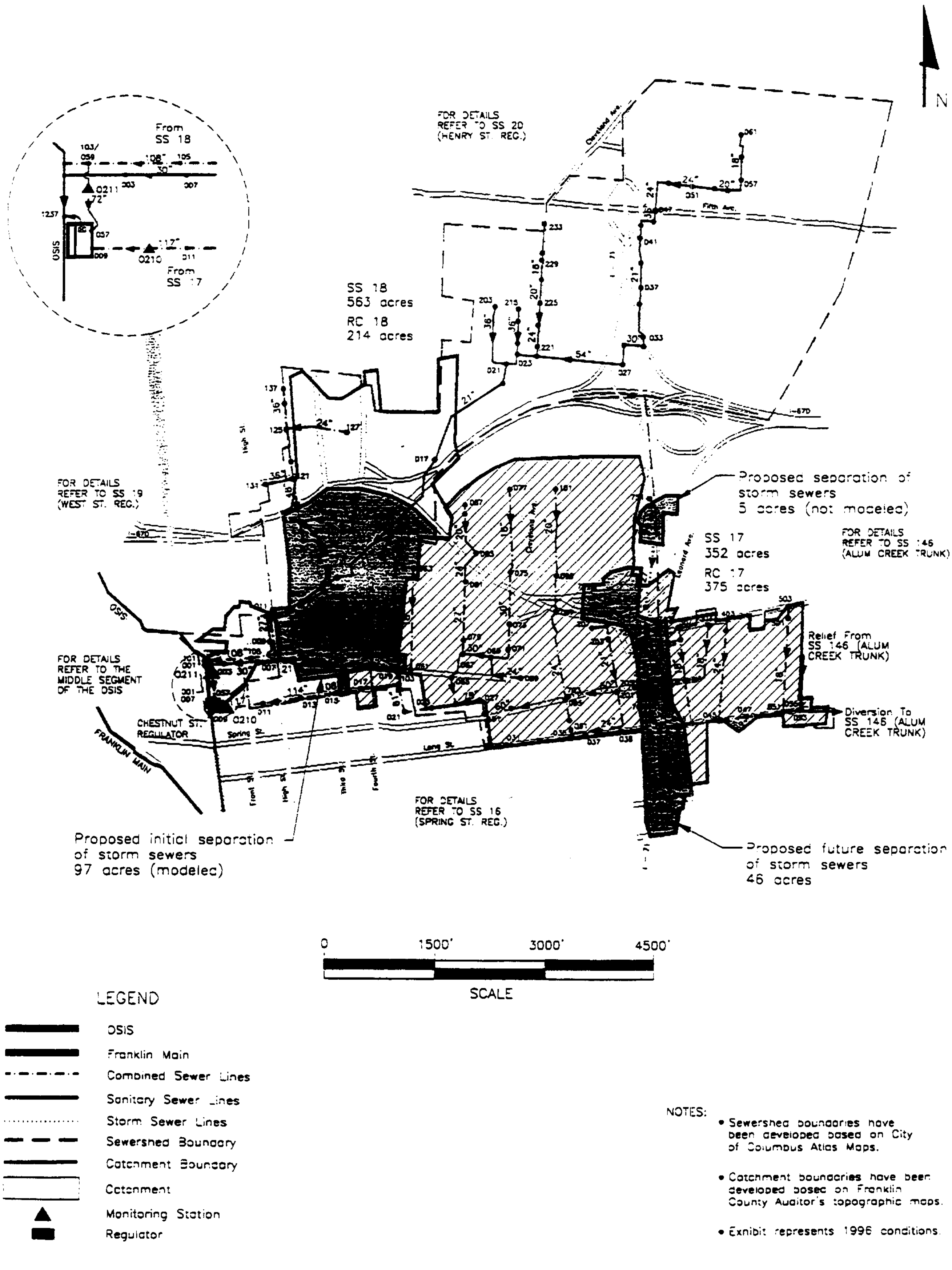


Figure 1. Tributary Runoff Catchment and Sanitary Sewershed to Chestnut Street Regulator

SEPARATION MODEL APPLICATION OBJECTIVES

During the development of the city's Combined Sewer System Operational Plan, the CSCS hydraulic model was used to determine remaining capacity within the city's interceptors. Prompted by questionable record plan information, unknown field conditions (are bulkheads in place, level of debris in chamber, etc.), and unexpected frequency of simulated reverse flow conditions through an upstream regulator, further investigation into the proposed Chestnut Street Separation Project was undertaken. An application of the model was developed to answer the following questions and verify the CSO Study recommendations:

1) *Will the proposed separation improve collection system performance?*

2) *Will the proposed separation negatively impact the streams?*

FLOW MONITORING AND RAINFALL DATA

A comprehensive Flow Monitoring and Rain Gauge Program was developed in conjunction with the CSCS hydraulic model development. This program's objectives are to provide the CSCS team with information on the collection systems hydraulics during dry and wet weather. A network of sixty four (64) flow monitors and thirty nine (39) rain gauges are owned and maintained by the DOSD. The model application was run using flow monitoring data captured during a 2-year storm event as recorded during the July 26, 1995 rain event.

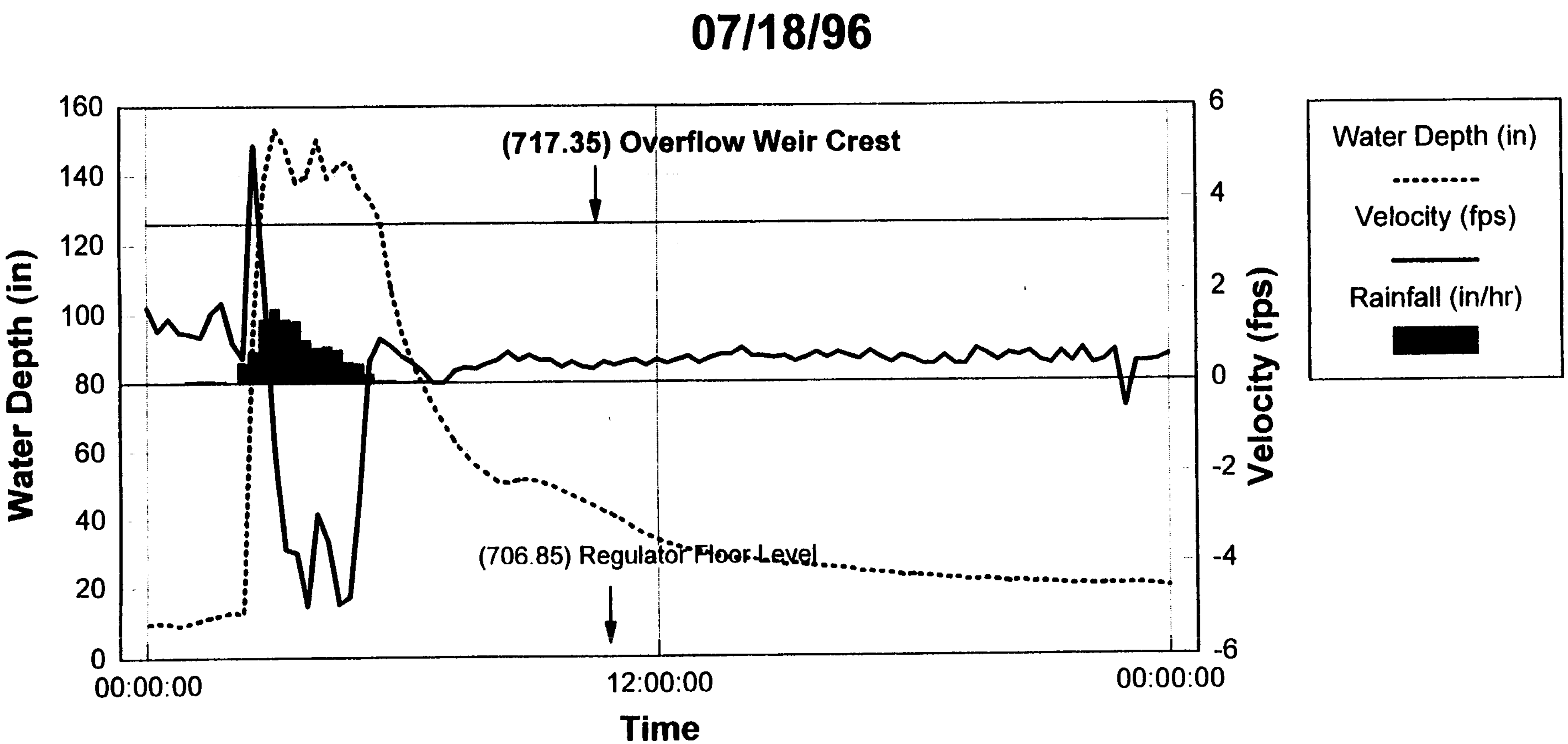
During the initial model application runs, flow data was provided by monitors located within the combined sewer system upstream and downstream of the Chestnut Street Regulator. An additional flow monitor was placed in the OSIS interceptor at a location between the WSST and the Chestnut Street Regulator following the initial model application runs.

HYDRAULIC MODELING EXERCISE

The Columbus Sewer Capacity Study uses historical rainfall events and measured flow data to calibrate the EPA Storm Water Management Model (SWMM) developed for the city of Columbus service area. This model is used to incorporate the collection system's physical description and meteorological data to determine the related hydraulic/hydrologic process. Original design reports were reviewed to determine basis of design criteria to compare to existing system conditions. The collection system is divided into smaller components based on the collection system drainage starting from service connections continuing to the point of interceptor discharge. The same procedure is followed in the runoff catchments (RC) based on topography of streets combined with linkage order of the CSS. All interceptors, including the Olentangy Scioto Intercepter Sewer (OSIS) are modeled using the SWMM EXTRAN block to consider the impact of surcharged conditions.

Initial model runs that were undertaken to evaluate remaining capacity in the OSIS shows that the Hydraulic Grade Line (H.G.L) inside the OSIS is higher than the weir crest elevation of a certain group of regulators. This indicates there may be reverse flow from the OSIS between this group of regulators. In addition, the H.G.L. in the OSIS is found to be below the overflow crest elevation of another group of regulators. This indicates that there may be no reverse flow to this group. To verify the model results, a flow meter was installed at Henry Street Regulator to record water depth and velocity at the intercepting connection. Figure 2 illustrates recorded water depth and velocity during the storm event on July 18, 1996. The recorded data shows that at the beginning of the storm, velocity pattern increases while water depth increases up to a certain time. When the water elevation rose above the weir crest elevation, the velocity pattern dropped and became negative, which indicates reverse flow and confirms the model results.

As shown in Figure 1, the Chestnut Street Regulator tributary area includes 563 acres (227 hectare) within sanitary sewershed (SS) 18, which includes 214 acres (86 hectare) of runoff catchments (RC). The initial proposed separation of 97 acres (39 hectare) of storm and combined sewers from RC 18 (as described in the 1989 CSO Study) would reduce the total RC area to 117 acres (47 hectare). The 108-inch (2700 mm) storm sewer to be removed from the OSIS, the subject of this modeling, has the design capacity to provide gravity storm sewer services to the runoff catchment in both SS 18 (RC = 375 acres) and SS 17 (RC = 214



Total rainfall = 2.9 in
Maximum rainfall intensity = 1.62 in/hr

Figure 2. HENRY Street Regulator Flow Observations at 07/18/96

acres). The second phase in this effort, would provide immediate removal of the 46 acres of Interstate roadway drainage from the tributary flow to the regulator.

The analysis included flow estimates of DWF and wet weather flow (WWF), and were entered as point sources at certain nodes in the collection system. The combined flow was routed in the SWMM EXTRAN. The Chestnut Street Regulator was described in the model as depicted in Figure 3, where a 66 x 66 inch sluice gate controls the flow from the regulator. The gate settings is 33 inches above floor level to allow a 66 x 33 inch opening. The overflow weir crest is set at elevation 717.88.

To investigate the impact of the separation, the RC is reduced to 117 acres in the SWMM RUNOFF model using the same historical rainfall data (7/26/1995- 2 year storm), and using the same parameters for current conditions.

MODELING RESULTS

The modeling results of the proposed initial separation of storm sewers (97 acres) indicate that the maximum computed flow rate in the 108 inch (2700 mm) sewer has dropped from 247 mgd (10.8 m^3/sec) to 200 mgd (8.76 m^3/sec). However, the computed maximum H.G.L. in the OSIS does not show significant change before and after the separation. Figure 4 illustrates a hydraulic profile of the OSIS showing computed maximum water depth and regulator elevations (i.e., weir crest level and floor level).

Table 1 lists all regulators that have been impacted by the separation showing computed overflow volume at each regulator before and after the separation.

The modeling results indicate the total reduction in overflow volume is approximately 0.52 MG (1,968 m^3) (0.42 at WSST and 0.11 at Henry Street Regulator).

Based on these results, the proposed separation is not expected to have a significant reduction in either overflow volume or overflow frequency at WSST for the 2 year storm level.

Table 1. Combined Sewer Overflow Reduction: 2-Year Storm Event

Node Number	Overflow Location	Volume of Overflow				Reduction in Overflow Volume 2 Year Event		
		Before Separation		After Separation				
		(MG)	(m^3)	(MG)	(m^3)	(MG	(m^3)	(%)
1201	Whittier Street Storm Tanks	164.3	621,876	163.9	620,362	0.419	1,586	0.3
12101	Rich Street Regulator O/F	0.029	110	0.024	91	0.005	19	17.0
13101	Town Street Regulator O/F	0.013	49	0.013	49	0.000	0	0.0
15101	Long Street Regulator O/F	0.085	322	0.072	273	0.013	49	15.0
16101	Spring Street Regulator O/F	0.915	3,463	0.839	3,176	0.022	83	2.0
1703	Chestnut Street Regulator O/F	0.000	0	0.000	0	0.000	0	0.0
20101	Henry Street Regulator O/F	2.821	10,677	2.710	10,257	0.111	420	4.0
21201	First Avenue Regulator O/F	0.082	310	0.076	288	0.006	23	7.0
23101	King Avenue Regulator O/F	0.092	348	0.085	322	0.007	26	8.0

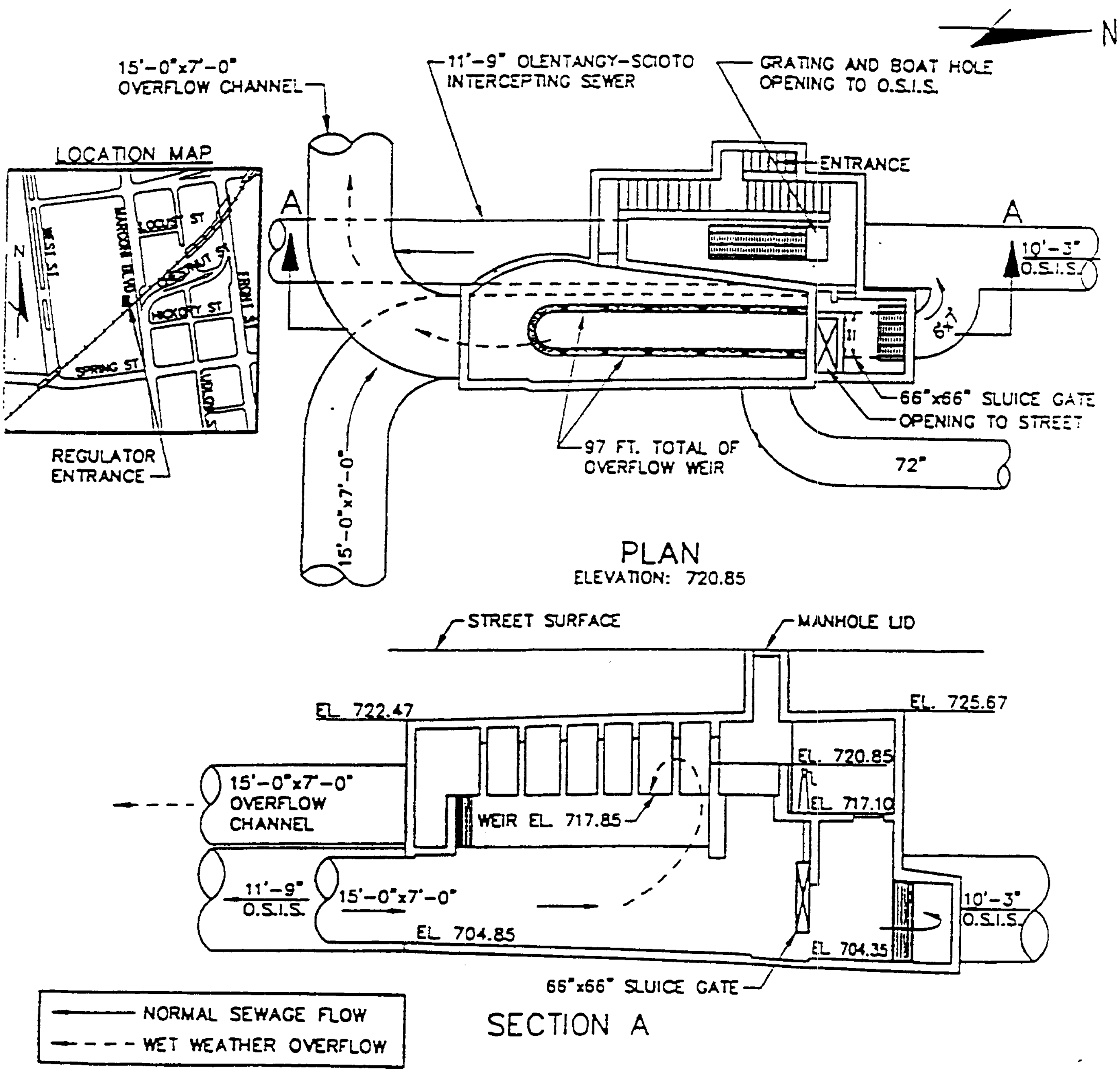


Figure 3. Plan and Profile of the Chestnut Street Regulator (Pirnie, 1996)

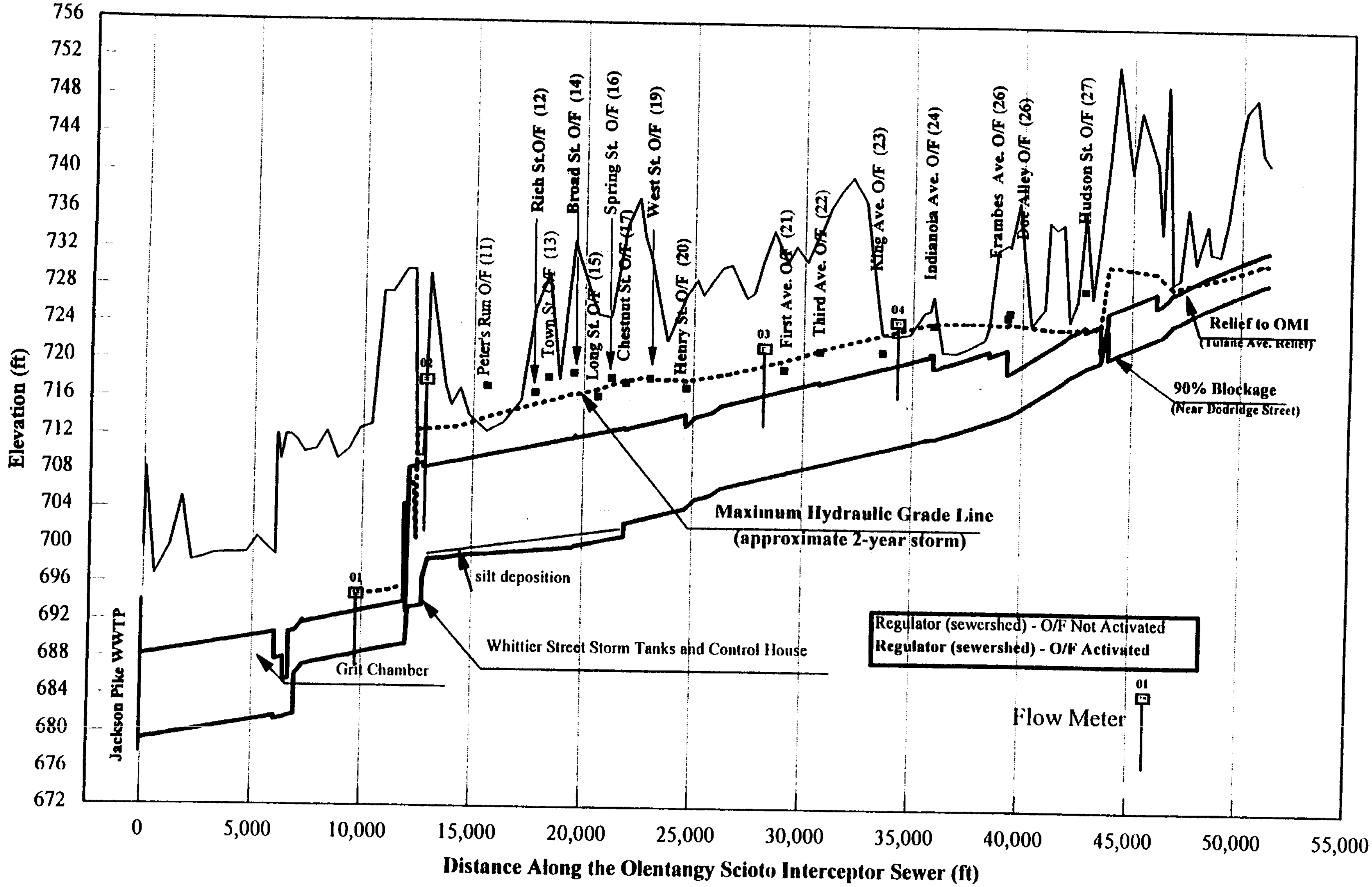


Figure 4. Maximum Computed Hydraulic Grade Line Along the Olentangy Scioto Interceptor Sewer (OSIS) During the High Intensity Rainfall Event (approximate 2-year storm)

FIELD VERIFICATION

Verification of actual field conditions is recommended when the level of certainty of modeling results is critical. During the detailed modeling of the Chestnut Street Regulator, questions were raised as to whether or not the record plans reflected as-built conditions. Specifically, there were two bulkheads shown on the record plans that were to be installed during the final stages of construction. Verification that these bulkheads are in place was performed by the CSCS field crew who also noted the following:

a. Substantial debris was observed within the Chestnut Street Regulator structure during a December, 1996 CSCS field crew site visit. This regulator is extremely difficult for maintenance crews to clean due to location, chamber design, and depth of deposits. During a May, 1997 field crew site visit, it was noted that the regulator structure had been cleaned, with little deposition built up.

b. Deposition was observed to be clogging the 72-inch (1800 mm) diameter storm sewer pipe entering the OSIS within the Chestnut Street Regulator structure during the December, 1996 site visit. During the May, 1997 site visit, this pipe is open and flowing into the OSIS.

c. Recommended locations for flow monitor installations were investigated. Installation and maintenance of proposed flow monitors within the 72-inch by 84-inch (1800 by 2100 mm) connection between the OSIS and the regulator gate may be difficult due to the hazardous flow conditions.

These observations provide very useful information that can support the prediction of reverse flow through the Chestnut Street Regulator and infrequent activation of the overflow weir during high intensity storm events.

In addition to the site visits performed by the CSCS field crew, the Stormwater Management Program currently monitors overflows at all regulators within the CSS. The location of a wooden block initially placed on the weir wall in each regulator is checked on a periodic basis. Historical data collected by the stormwater group do not indicate block movement at the regulators not expected to activate, further supporting the confirmation of model application findings.

FURTHER RECOMMENDATIONS

Based upon the results of the CSCS model application described in this paper, the following recommendations were identified as beneficial to undertake prior to the DOSD proceeding with the proposed Chestnut Street Separation project:

1. Continue the use of the CSCS hydraulic model and flow monitoring program to optimize the performance of all of the regulators by simulating modifications to weir elevations and gate settings. Assuming negligible spatial variation of rainfall, discharge of combined flows during wet weather should occur at the storm tanks until the regulators simultaneously crest their weir elevations.

2. Continue use of the CSCS model to analyze incremental levels of rainfall to determine the receiving stream's level of protection from combined sewer overflows presently provided by the combined sewer system. In addition, determine the level of stream protection at Chestnut Street following separations and optimization of the combined sewer system.

Findings of these two exercises can be used to aid in determining whether or not to proceed with the separation project.

3. If the DOSD proceeds with separation work, implement a flow monitoring program of the Olentangy Scioto Interceptor Sewer, WSST, and Chestnut Street Regulator before and after the construction of separation work to determine separation efficiency.

CONCLUSIONS

The application of the Columbus Sewer Capacity Study hydraulic model, supported by the use of flow monitoring data and field verifications obtained by the CSCS field crew proved to be a very valuable exercise. It successfully demonstrated that it is crucial to consider global impacts as well as local impacts during the decision making process of whether to separate or not separate combined sewer flows. Not only did the preliminary results as stated in this paper indicate that the impact of separation work may provide insignificant improvements in water quality, the results indicate that there may be other improvements that can be made to the system to more effectively spend capital improvement program funds to realize greater benefits to the receiving stream.

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Simulating Infiltration and Inflow in Sewer Systems using SWMM RUNOFF

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ABSTRACT

Creating effective plans to address sanitary sewer overflows requires good understanding of collection system response under a variety of operating conditions. To extend the usefulness of measured data, the Greater Vancouver Sewerage and Drainage District modified SWMM RUNOFF to improve simulation of wet weather flows in sanitary sewers through computer modelling. The addition of an effective infiltration area factor and improvements to tracking head differences between the groundwater stage and pipe tailwater level produced calibrated results that were typically ±15% of measurement. This level of accuracy in simulating immediate and seasonal infiltration and inflow response provides the basis for evaluating a wide range of options that address wet weather issues.

KEYWORDS

SWMM, RUNOFF, infiltration, inflow, sanitary sewer, overflow, computer simulation.

INTRODUCTION

Rainfall-induced infiltration and inflow (I/I) is described as the seepage of percolating rainwater that finds its way into the sanitary sewer system through pipe defects. While rainfall-induced I/I occurs during and some time after the rainfall event, it can result in peak flows that exceed sewer design capacities culminating in sanitary sewer overflows (SSOs). Reactive measures to eliminate SSOs by up-sizing flow conveyance and treatment capacities will often lead to a path of high-cost solutions. Improving one's understanding of I/I and engaging in a thorough assessment of improvement options can provide a set of cost-effective solutions to address SSOs. Computer simulation of I/I is one of several program steps the Greater Vancouver Sewerage and Drainage District (GVS&DD) is undertaking to identify, quantify, and evaluate system improvements.

Objectives of this computer modelling effort included:

- Minimizing discrepancies between measured and simulated I/I under a wide variety of rainfall patterns and antecedent moisture conditions.
- Extrapolation of I/I response to unmonitored areas and to extended durations that cover seasonal variations.
- Overall assessment of existing sewer system performance for light and heavy rainfall years.
- Performance evaluation of options such as increased conveyance, treatment capacity, I/I source reduction, and peak flow storage.

This phase of work focuses on modelling the hydrological process of rainfall, groundwater percolation, and infiltration to sanitary sewers.

Previous I/I Modelling Methods

Various methods of estimating I/I can be categorized as follows:

(i) direct measurement;
(ii) application of unit infiltration rates;
(iii) the multiple unit hydrograph approach; and
(iv) the physically-based approach.

Direct measurement of I/I is required in any program aimed at identifying and quantifying a realistic flow response to rainfall. It is generally the first step to defining the extent of the problem. However, measurement devices generally can not be located everywhere in the collection system and maintained indefinitely given the cost implications. Direct measurement's ability to assess existing response will provide a means of checking indirect methods, but it will not provide estimation of future response or under "what-if" scenarios.

Unit infiltration rates empirically derived from measured data are widely used for design purposes. Its use precludes modelling of a system's hourly or minute-by-minute response to actual rainfall. Unit infiltration rates are typically not correlated to return period storms, but rather represent rules-of-thumb.

Because of its simplicity, the multiple unit hydrograph approach is by far the most often used method to estimate I/I response. For example, the City of Edmonton applied a three unit hydrograph model that describes: fast inflow; fast infiltration; and slow infiltration (Christopher et al., 1996). The City of Alexandria in Virginia applied a two unit hydrograph model to simulate fast and slow I/I components (Oakley and Warren, 1995). The main drawbacks of the multiple unit hydrograph approach are: (i) it does not provide a physical insight to the hydrologic processes, but treats it as a "black-box"; (ii) it generally does not consider the effect of antecedent moisture conditions; and (iii) it assumes processes are linear.

In comparison to multiple unit hydrograph models, there has been limited development in physically-based I/I estimation models. One notable example was the CEMGREF model developed in France for application in rural watersheds (Belhadj et al., 1995). While the CEMGREF model provides a physically-based approach that accounts for hydroclimatic conditions, as well as, surface and subsurface characteristics, the developers have indicated that it does not simulate urban sanitary sewer systems to desirable levels of accuracy.

METHODOLOGY

Since the early 1990's, the GVS&DD has successfully used the RUNOFF module of the Storm Water Management Model (SWMM) to simulate the hydrologic process for several of its combined sewer overflow studies and programs. Early attempts to apply the same approach to sanitary sewer systems highlighted weaknesses in RUNOFF's ability to adequately describe the physical process. While peak flows could be made to match field measurements, simulated storm recessions and nightly low flows differed substantially both during and after storm events. Also noted and confirmed by field measurement was that sanitary discharges account for a substantial portion of the flow depth, even during storm events in sanitary sewers. This effect is much less pronounced in combined sewers.

On the basis of these observations, it appeared that sanitary discharges can effectively 'regulate' groundwater I/I via diurnal fluctuations in the tailwater depth in the sewer. Given that the difference in elevation between the groundwater table and the tailwater depth provides the driving head for infiltration, diurnal variations in the tailwater depth would tend to decrease infiltration potential during sanitary peaks and conversely increase infiltration potential during nightly low flow periods (see Figure 1). To properly account for this physical process, the RUNOFF module would need to deal with dry weather flow inputs for regulating groundwater flow in its subroutines.

Recognizing that sanitary sewers and storm drains typically share the same catchment area in an urban environment, one can describe the area of I/I contribution to the sanitary sewer as a fraction of the total catchment area. Many other factors such as pipe depth, material, age, condition, existing quality of joints, and number of connections also influence the effective area of I/I contribution (see Figure 2). Hence, the idea of introducing an effective I/I contributing area factor, α, a user-defined value as a fraction of the total catchment surface area.

Modifications

Version 4.31 of RUNOFF provided the basis of implementing concepts surrounding input of dry weather flows and application of an effective area factor. The modified version of RUNOFF named v4.31d now provides the option of:

- including 24-hourly, 7-day, or long-term dry weather flows to any given subcatchment
- applying an effective area factor for I/I contributions to any given subcatchment.

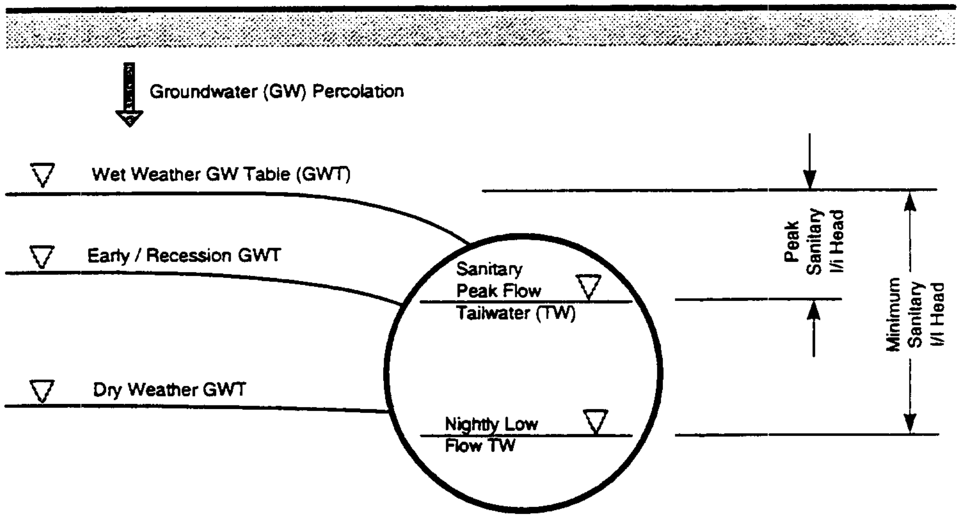

Figure 1. Conceptualization of tailwater effects that tend to decrease I/I potential during sanitary peaks and increase I/I potential during nightly low flows.

Figure 2. Conceptualization of a user-defined effective I/I contributing area factor as a fraction of the total catchment surface.

In addition, the functional form of the groundwater flow equation (GWFLW) was modified slightly to better describe the head difference concept.

The standard version of SWMM RUNOFF uses a groundwater equation to calculate infiltration flow at any given time-step using equation (1) given by the following:

$$I/I = a_1(GWT - PI)^{b_1} - a_2(TW - PI)^{b_2} + a_3(GWT)(TW) \quad (1)$$

where GWT = the water table elevation; PI = pipe invert elevation; TW = the tail water elevation; and a_1, a_2, a_3, b_1, and b_2 = discharge coefficients.

Note that the standard equation does not directly represent the driving head for groundwater infiltration flow given by the difference (GWT - TW). Only in the event if $a_1 = a_2$, $b_1 = b_2$ would equation (1) provide the (GWT - TW) head potential.

The revised groundwater equation is given by equation (2).

$$I/I = a_1(GWT - TW)^{b_1} - a_2(TW - PI)^{b_2} + a_3(GWT)(TW) \quad (2)$$

GVS&DD staff tested modifications to RUNOFF v4.31 on dozens of catchment models which calibrated with generally good results. Figure 3 shows a schematic of the calibration process and revised data flow paths.

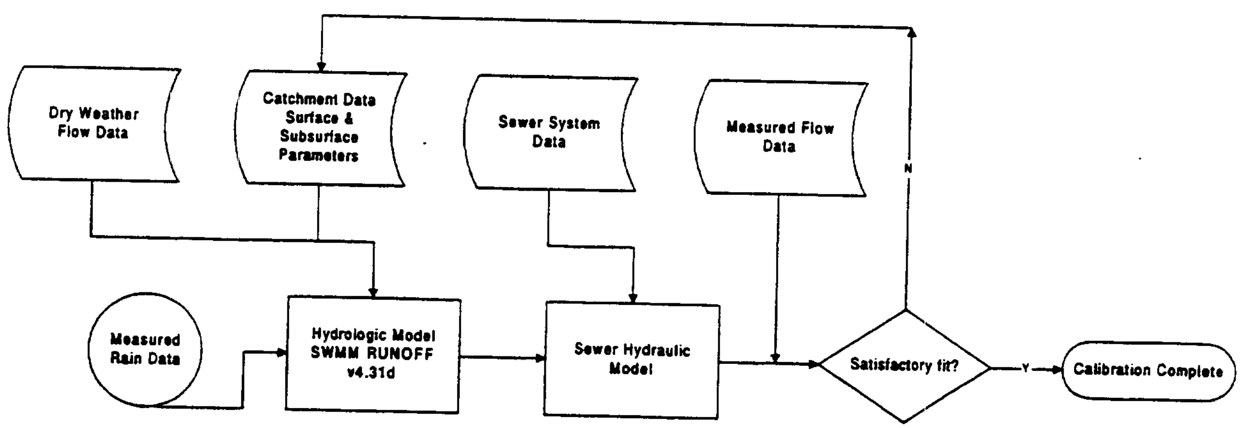

Figure 3. Schematic of the calibration process and data flow paths.

Notes on the Calibration Process

- As shown in Figure 3, dry weather flow data is now an input to the hydrologic model, RUNOFF, rather than its input traditionally into the sewer hydraulic model. All calibrations included hourly dry weather flow patterns for each catchment over a 7-day period.

- Sewer catchments were typically discretized into 50 ha areas. Physical catchment data such as area, average slope, width, capillary suction, hydraulic conductivity, and porosity were estimated either by measurement or interpolated from book values; most parameters with no or little adjustment during calibration. Discharge coefficients and true calibration parameters were used extensively to obtain satisfactory simulated results.

- Historical rain data from 20 tipping bucket gauges distributed over the study area at a density of about one gauge per 2000 ha were used. Recent flow data were available at 44 upper catchment sites to calibrate the hydrologic and hydraulic models.

- RUNOFF's simple hydraulic model was used to calculate the tailwater elevation for each catchment. Only the subsurface flow component was considered in simulating I/I flows. Surface runoff was assumed to discharge into appropriate drainage systems.

- Simulation start-times were set to well ahead of the comparison period to ensure stabilization of ground conditions (e.g., soil moisture; groundwater table) from initial values.

RESULTS

Figure 4 (a) shows an example of simulation results using the standard version of RUNOFF v4.31. It appears that without the modifications, low flows, peak flows, and time to peak flows are not well simulated. The poor fit is likely a function of not correctly balancing the fast and slow I/I responses. In this particular case, there appears to be over-storage of percolated flows resulting in overestimation of I/I as the groundwater equation continues to release water well after the rain storm has ended.

Figure 4 (b) shows the results of including the effective area factor. The prediction of low flows after the storm is improves somewhat, but at the expense of poor fit during peak storm flows.

Adjustment of groundwater equation coefficients, the subsurface hydraulic conductivity, and the field capacity produced the final calibrated result shown in Figure 4 (c). The subsurface hydraulic conductivity was increased to accelerate I/I response so that the time to peak could be better simulated. The overall fit is substantially improved, but with some loss in accuracy during the storm of 27-Dec.

Calibration of the first few catchments took significant effort as parameter sensitivities were explored. Experience grew with each catchment calibrated, providing insight on how to accelerate the calibration process. One simplification made to nearly all models involved reducing the groundwater equation to only the first term with starting coefficients as follows:

Table 1. Default coefficient values in Equation 2.

Parameter	a_1	b_1	a_2	b_2	a_3
Default value	20	0.001	0.0	0.0	0.0

The calibrated value of the effective area factor varied significantly from 5% to 20%.

Once calibrated, the hydrologic model can extend its application to:
- continuous simulations
- estimation of I/I response to any storm (e.g., historical high, low, new data, return-period design storms)
- extrapolation to unmonitored areas (via parameter transference).

As an example, Figure 5 shows two snapshots of a 12-month continuous simulation run, to which only 4 months of measured data exists over the simulation period. Total flows as well as rainfall-induced infiltration and inflow can be determined by year, by season, or by day to assess wet weather performance of the upstream collection system. A review of such statistics for the dozens of calibration points or hundreds of extrapolated and interpolated points will help to identify areas with particularly excessive I/I. The areas can then be prioritized for targeted I/I reduction programs.

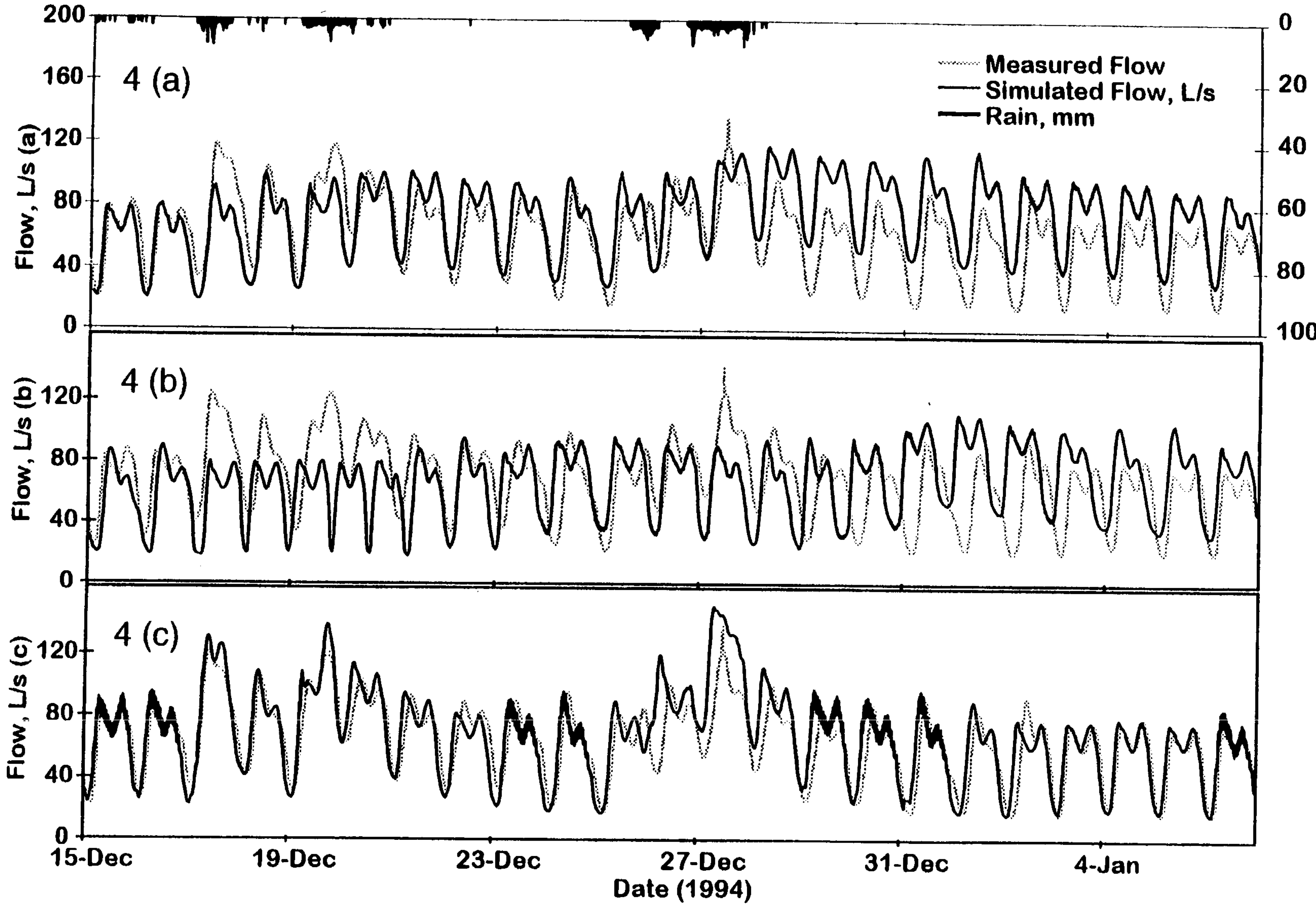

Figure 4. Comparison between standard and modified RUNOFF models. (a) using standard RUNOFF v4.31, (b) with the use of the effective area factor, and (c) with modified RUNOFF that considers tailwater effects of sanitary discharges.

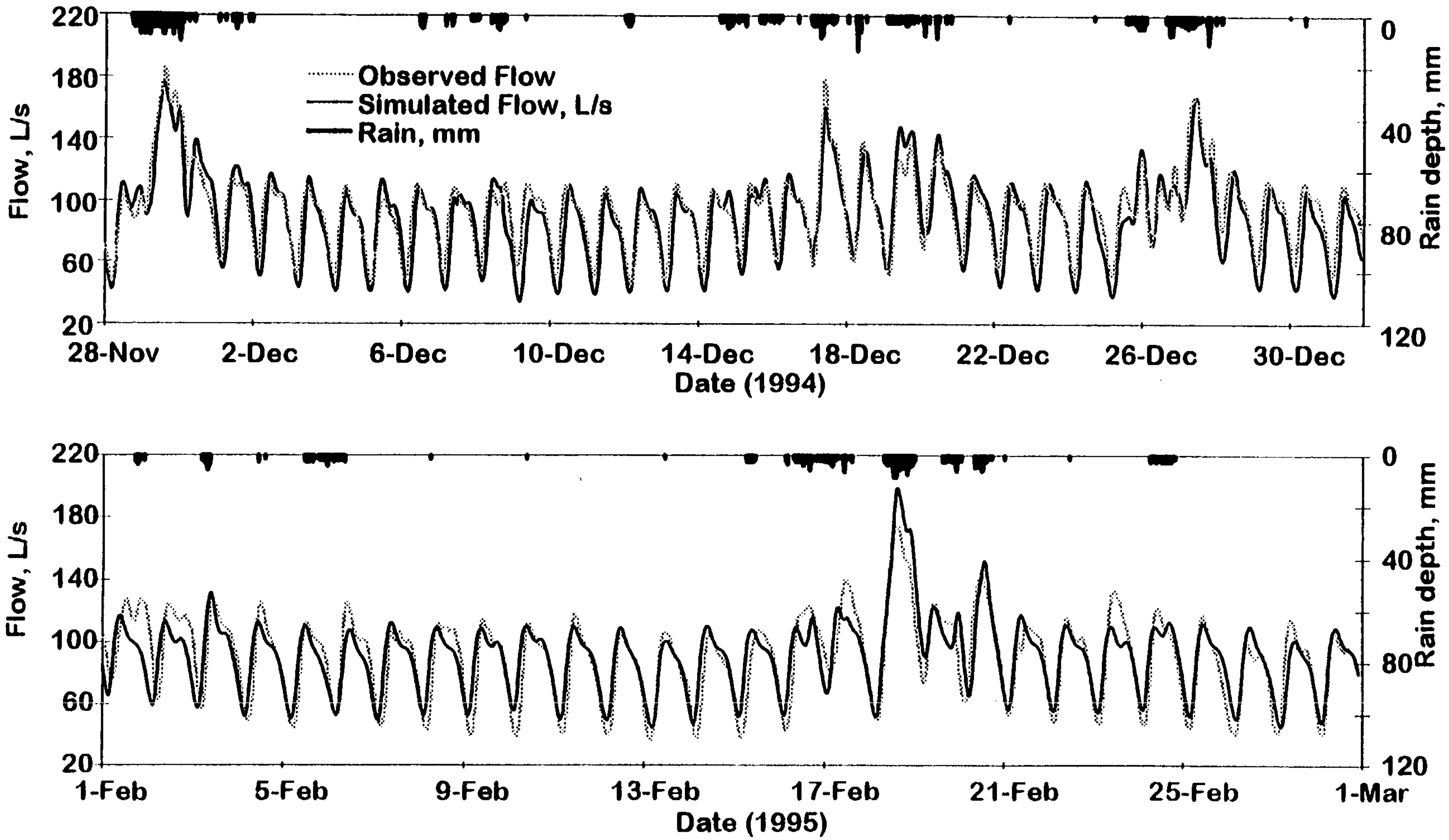

Figure 5. Two snapshots of a 12-month continuous simulation run.

DISCUSSION

In general terms, RUNOFF's subsurface routines can be conceptualized as flow movement in and out of a non-linear reservoir. For the most part, the effective I/I contributing area, the depth of pipe, field capacity and porosity define dimensions of the reservoir. The percolation process and associated parameters such as hydraulic conductivity and moisture content determine the inflow rate into the reservoir. The groundwater equation and its discharge coefficients describe the release rate out of the reservoir.

Catchments characterized by significant I/I, even days after the storm event, can be represented by a large reservoir volume and small discharge coefficients at its outlet. Conversely, catchments with quick I/I response can be represented by a small reservoir volume, large discharge coefficients, and high percolation rates. Using this physically-based conceptualization helps to better understand the I/I process and often leads to highly satisfactory results. As with any other physically-based approach, RUNOFF v4.31d can be readily applied to other geographic areas with starting parameters from known values set for the new study area before calibration begins.

The modifications to RUNOFF have substantially improved its ability to successfully simulate wet weather conditions for a sanitary sewer system. However, simulated results still show some discrepancy from measurement. While there could be a variety of reasons for this, a few are suggested:

- The I/I process is much more complex than can be described by reservoir concepts. RUNOFF is a deterministic one-dimensional model that averages I/I processes over a relatively large catchment. In reality, there exists a wide variation of conditions that can not be described by the simple concepts used in RUNOFF. For example, sewers within a catchment are located at different elevations; the I/I contributing area varies; there are other sources of drainage such as storm sewers, ditches, deep percolation, and evapotranspiration.

- To offer a means of balancing inflow versus infiltration, the original intent was to implement a separate effective area factor for surface and subsurface flow components in RUNOFF. Programming difficulties forced compromise to a single effective area factor for both the surface and subsurface components.

- RUNOFF v4.31d is able to deal with infiltration when the groundwater table is at a higher elevation than the tailwater level in the sewer. However, exfiltration is currently not modelled, should the groundwater table drop below the tailwater elevation.

- In some cases, sewer backwatering occurs which could significantly impact the actual tailwater elevation. RUNOFF's simple hydraulic model is not able to model such effects.

CONCLUSIONS

This paper presents a new approach to infiltration and inflow analysis in separated system. The approach uses a modified version of the SWMM RUNOFF model, which includes the following: (i) addition of an effective area factor to control the I/I contributing area, and (ii) consideration of sanitary discharge influences on the tailwater depth in estimating I/I.

The effective area factor provides a means to control the I/I contributing area and thus the I/I volume. It appears that the rate of I/I release can be adequately controlled using 2 of 5 coefficients in RUNOFF v4.31d's groundwater equation.

Sanitary flow can have a significant influence on I/I contributions through tailwater effects. The presence of sanitary flow increases the tailwater elevation, reducing the driving head differential with respect to the groundwater stage. RUNOFF v4.31d accounts for tailwater fluctuations due to sanitary discharges and rainfall-induced flow components.

Calibrated hydrologic models using the modified version of RUNOFF produced very good results when applied to sanitary sewer systems spanning some 36,000 ha. The GVS&DD uses RUNOFF v4.31d to investigate sewer overflows, address operating and maintenance issues, extrapolate I/I response to unmonitored areas, supplement measured flow data, and evaluate sewer improvement options under a variety of rainfall patterns.

ACKNOWLEDGMENTS

The authors thank Brett Young, M.Sc., P.Eng., for his insight during the conceptualization stage of this project. We recognize Dr. Zhong Ji, Ph.D. for his effort in programming our algorithms into what could be considered the most tinkered FORTRAN source code in history. We also thank the Reid Crowther Consulting team in Seattle for their support.

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HISTORICAL PERSPECTIVE

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ABSTRACT

This presentation provides the historical perspective and background for the nine following presentations regarding various aspects of the Northeast Ohio Regional Sewer District wet weather programs.

KEYWORDS

wastewater, treatment, sewer, combined, overflow, Erie, Cuyahoga

CONDITIONS IN THE LATE 1960s AND EARLY 1970s

Water quality during the late 1960s and early 1970s was definitely impaired. The Cuyahoga River and Lake Erie were polluted by sanitary and industrial wastewater. Numerous oil spills occurred at combined sewer overflows. The Cuyahoga River "burned" in 1969. Beaches were routinely closed. "Help - I'm dying" was painted on a break wall on Lake Erie.

There was also tension among all levels of government. Federal agencies filed litigation against the City of Cleveland for polluting the Cuyahoga River and Lake Erie. State agencies placed a building ban on Cleveland and other communities connected to the Cleveland sewer system. The communities filed litigation against Cleveland over sewer rate inequities. All litigations were consolidated into one case.

NORTHEAST OHIO REGIONAL SEWER DISTRICT

The Northeast Ohio Regional Sewer District was created by the court order ending this case in July, 1972. The District was made responsible for wastewater treatment, interceptor sewers, combined sewer overflow control, industrial waste control, and development of a plan for regional management of wastewater collection and storm drainage.

The court order defined Subdistrict 1 to be Cleveland and Subdistrict 2 to be all other communities. The order then specified that the District would be governed by a seven-member Board of Trustees, appointed as follows:

- Two by the Mayor of Cleveland
- Two by a Suburban Council of Governments
- One by the Commissioners of the County of Cuyahoga
- One by the Subdistrict with the greatest wastewater flow (currently Subdistrict 1)
- One by the Subdistrict with the greatest population (originally Subdistrict 1, but now Subdistrict 2)

The District currently has a 295 square-mile service area, which includes 75 square miles served by combined sewers. The service area encompasses all or part of 53 communities, each responsible for their own local sewer system. The District serves over one million people and treats over 330 million gallons of wastewater per day on average.

The District owns and operates three wastewater treatment plants, six pump stations, 207 miles of interceptor sewers, 467 static combined sewer regulators, and 29 automated combined sewer regulators. The 496 combined sewer regulators discharge to the environment at 126 locations permitted by the National Pollutant Discharge Elimination System. Discharges at these 126 locations impact many receiving waters:

- Lake Erie
- Four streams tributary to Lake Erie
- The Cuyahoga River
- Four streams tributary to the Cuyahoga River
- The Ohio Canal

WET WEATHER PLANT OPERATION

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ABSTRACT

The creation of the Northeast Ohio Regional Sewer District by court order in 1972 was done to resolve water quality problems that existed in the greater Cleveland area. These problems were due in part to the inability of treatment facilities to treat wet weather flows. Today, the three award winning treatment plants have been exemplary in their day to day operation. Beyond that, they have maintained their permit conditions utilizing strategies to deal with high flows during wet weather conditions. Each plant is unique and this paper explores their uniqueness in handling wet weather operations.

KEYWORDS

wastewater, treatment, wet weather, process, flow

INTRODUCTION

The Northeast Ohio Regional Sewer District operates three-wastewater treatment plants in the Cleveland area. The oldest facility is the Easterly Wastewater Treatment Plant that is located on the east side of Cleveland and discharges into Lake Erie. The largest facility is the Southerly Wastewater Treatment Center located on the south side of the City of Cleveland in Cuyahoga Heights. This facility discharges its treated effluent into the Cuyahoga River. The smallest of the three plants is the Westerly Wastewater Treatment Plant located on the west side of City of Cleveland and discharges its treated effluent into Lake Erie.

EASTERLY WASTEWATER TREATMENT PLANT

The Easterly Treatment Plant is a conventional activated sludge plant with a design dry weather flow of 155 MGD and a wet weather flow of 330 MGD. The plant has no conventional solids handling facilities. The plant pumps it solids through a thirteen- mile pipeline to the Southerly Treatment Plant. The plant's National Pollutant Discharge Elimination System (NPDES) Permit has thirty day limits of 15 milligrams/liter (mg/l) carbonaceous biochemical oxygen demand, 20 mg/l suspended solids and 1.0 mg/l total phosphorus in the effluent.

Process Flow Scheme

The flow enters the plant, as show in Figure 1, through one of three interceptors-Collingwood, Heights-Hilltop or Easterly. When the flow is within the design criteria it receives preliminary treatment consisting of screening, grit removal and comminution. Flow is then measured and given primary treatment. After primary treatment, the flow goes into the activated sludge process in the step feed mode. From the final clarifiers the effluent is disinfected with sodium hypochlorite and dechlorinated with sodium bisulfite. The water elevation in the final clarifiers is lower than the present lake level; therefore, the effluent is pumped by screw pumps up to the lake level.

Wet Weather Flow

In wet weather, when the total plant flow is less than 330 MGD the Collingwood pumps lift all flows less than 100 MGD into the plant and the Heights-Hilltop and Easterly interceptors will flow by gravity into the plant.

When the total plant flow exceeds 330 MGD and the Collingwood flow is greater than 100 MGD the excess flow in the Collingwood interceptor overflows a fixed weir and automatically bypasses the treatment process. This plant receives approximately 0.250 MGD of water plant sludges. When the plant flow is near the bypass level, the wastewater plant has an automatic telephone dialer that sends a call to the water plant and informs them of the impending bypass. The water plants take the necessary action to shutdown their sludge pumping operation.

When the total plant flow exceeds 330 MGD and the Collingwood flow is less than 100 MGD the flow in the Collingwood interceptor is throttled. This is done by shutting down the Collingwood pumps to allow an overflow of the fixed weir and automatically bypass the treatment process. Again, when this occurs, the wastewater plant's automatic telephone dialer sends a call to the water plant and informs them of the impending bypass. The water plants take the necessary action to shutdown their sludge pumping operation.

The wet weather-operating scheme for this plant is to accept the more concentrated sanitary flows and to allow the more dilute sewage to be bypassed. Therefore, the plant will allow the flow from the Collingwood Interceptor to overflow first and then bypass from the Easterly Interceptor. As a last resort, if the flow from the Heights-Hilltop Interceptor exceeds the 330-MGD it will be allowed to bypass.

SOUTHERLY WASTEWATER TREATMENT PLANT

The Southerly Treatment Plant is a conventional two-stage activated sludge plant with a design dry weather flow of 200 MGD and a wet weather flow of 735 MGD. The plant's National Pollutant Discharge Elimination System Permit (NPDES) has thirty day limits of 16 milligrams/liter (mg/l) carbonaceous biochemical oxygen demand, 16 mg/l suspended solids and 1.0 mg/l total phosphorus in the effluent.

Process Flow Scheme

As shown in Figure 2, the flow enters the plant through one of five interceptors-Big Creek, Mill Creek, Cuyahoga Valley, Southwest or Southerly. In addition, sludge from the Easterly treatment plant is pumped into the influent of Southerly. When the flow is within the design criteria it receives preliminary treatment consisting of screening, grit removal. Flow is then measured and given primary treatment. After primary treatment the flow goes into the first-stage activated sludge process currently operated in the step-feed mode. After the first-stage treatment the flow is pumped to the second-stage activated sludge process for nitrogen removal. From the final clarifiers the effluent flows through gravity sand filters. It is then disinfected with sodium hypochlorite and dechlorinated with sodium bisulfite. The plant discharges its treated effluent by gravity to the Cuyahoga River.

Solids handling consists of primary sludge cyclone degritting, gravity thickeners and gravity belt thickeners. A medium-pressure thermal conditioning process to prepare the sludge for dewatering. Centrifuges and vacuum filters dewater the thermally conditioned sludge and incinerators to reduce the volume of sludge. Since the plant receives sludge from the Easterly treatment plant, it must process about twice the amount of sludge that a plant with the same flow would process.

Wet Weather Flow

In wet weather, when the flow to Southerly is less than 175 MGD, the total plant flow will receive preliminary, primary, first-stage, second-stage treatment and filtration. The full flow is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the river.

When the flow exceeds 175 MGD, but is less that 400 MGD, the flow receives preliminary and primary treatment. Only 175 MGD of this flow receives first-stage treatment. However, the full flow up to 400 MGD goes to the second-stage and receives secondary treatment. The flow up to 400 MGD can be filtered. The full flow is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the river.

When the flow exceeds 400 MGD, but is less than 735 MGD, the flow receives preliminary and primary treatment. The flow exceeding 400 MGD, up to 335 MGD, will receive this degree of treatment. Of the remaining flow, only 175 MGD of this flow receives first-stage treatment. However, the full flow of 400 MGD goes to the second-stage and receives secondary treatment. The flow up to 400 MGD can be filtered. The 400-MGD flow is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the river. The portion of the flow above the 400-MGD is discharged to the river.

The wet weather operating scheme for this plant is to provide maximum treatment to the concentrated sanitary flows and reduce the amount of treatment when the flows becomes diluted with rain water. All available tankage in the primary and secondary is used for storm flow retention or flow through.

WESTERLY WASTEWATER TREATMENT PLANT

The Westerly Treatment Plant is a trickling filter/solids contact (TF/SC) biological process plant with a design dry weather flow of 33 MGD and a wet weather flow of 100 MGD. The plant's National Pollutant Discharge Elimination System Permit (NPDES) has thirty day limits of 15 milligrams/liter (mg/l) carbonaceous biochemical oxygen demand, 20 mg/l suspended solids and 1.0 mg/l total phosphorus in the effluent.

Process Flow Scheme

The flow enters the plant through one of two interceptors-Westerly and Northwest. Flows within the design criteria receive preliminary treatment consisting of screening, grit removal and comminution, as shown in Figure 3. Flow is then measured and given primary treatment. After primary treatment, the flow pumped up to one of three trickling filters. Then the flow goes to through the solids contact tanks and to the final clarifiers. From the final clarifiers the effluent is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged into Lake Erie.

The plant processes all biosolids collected from the wastewater. The plant uses gravity thickeners to thicken the solids. The plants centrifuges dewater the solids for the incineration process or in an emergency to transport the solids to an approved landfill.

Wet Weather Flow

In wet weather, when the flow to Westerly is less than 70 MGD the flow receives preliminary, primary and secondary treatment. The full flow is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the lake.

When the flow exceeds 70 MGD, but is less that 100 MGD, the flow receives preliminary and primary treatment. Only 70 MGD of this flow receives full secondary treatment. The remainder of the flow up to 100-MGD flows to blend with the secondary treated flow. The full flow is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the lake.

When the flow exceeds 100 MGD, but is less than 400 MGD, the flow up to 70 MGD receives preliminary, primary and secondary treatment. The plant will control the flow into the treatment facility by valves in the headworks so that the plant treats 100 MGD. The flow exceeding 100 MGD, up to 300 MGD, will receive preliminary and primary treatment utilizing the Combined Sewer Overflow Treatment Facility (CSOTF). The CSOTF is old Imhoff tanks converted to primary settling tanks with sludge withdrawal provisions. Only the treatment plant flow of 100 MGD is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the lake. The portion of the flow above the 100-MGD is also discharged to the lake.

When the flow exceeds 400 MGD, but is less than 1,800 MGD, only 70 MGD of the flow receives preliminary, primary and secondary treatment. Again, the plant controls the flow into the treatment facility by valves in the headworks so that the plant provides preliminary and primary treatment to 100 MGD. The flow exceeding 100 MGD, up to 1,800 MGD, will utilize the Combined Sewer Overflow Treatment Facility (CSOTF). Flows above 300 MGD are bypassed through the center channel to avoid tank flooding. As an added precaution, gates in the CSOTF pump building will also open to protect the catenary bar screens in conjunction with and effluent sluice gates on the influent center channel also open to regulate the flow. At this point, the plant is receiving higher flow rates than can be treated and the system bypasses the process. Only the treatment plant flow of 100 MGD is disinfected with sodium hypochlorite, dechlorinated with sodium bisulfite, and discharged to the lake. The portion of the flow above the 100-MGD is also discharged to the lake.

The wet weather operating scheme for this plant is to provide maximum treatment to the concentrated sanitary flows and reduce the amount of treatment when the flows becomes highly diluted with rain water.

CONCLUSIONS

During wet weather, the three plants are operated to take advantage of all available tankage in the primary and secondary process stream to be used for storm flow retention or flow through. This is evident in the peak wet weather event of February 27, 1997. The design wet weather capacity of the three plants is 1,365 MGD. Table 1 shows the flows handled by each plant on Thursday, February 27, 1997, when heavy rains and snow melt run-off taxed each plant to near capacity. The result was that 86 percent of the total capacity was utilized.

PLANT	FLOW	WW CAPACITY	% of CAPACITY
Easterly -	240 MGD	330 MGD	73%
Southerly -	709 MGD	735 MGD	96%
Westerly -	60.3 MGD	100 MGD	60%
CSOTF -	338.6 MGD	300 MGD	113%
Total =	**1,347.9 MGD**	**1,365 MGD**	**86%**

TABLE 1. Wet Weather Flow on Thursday, February 27, 1997

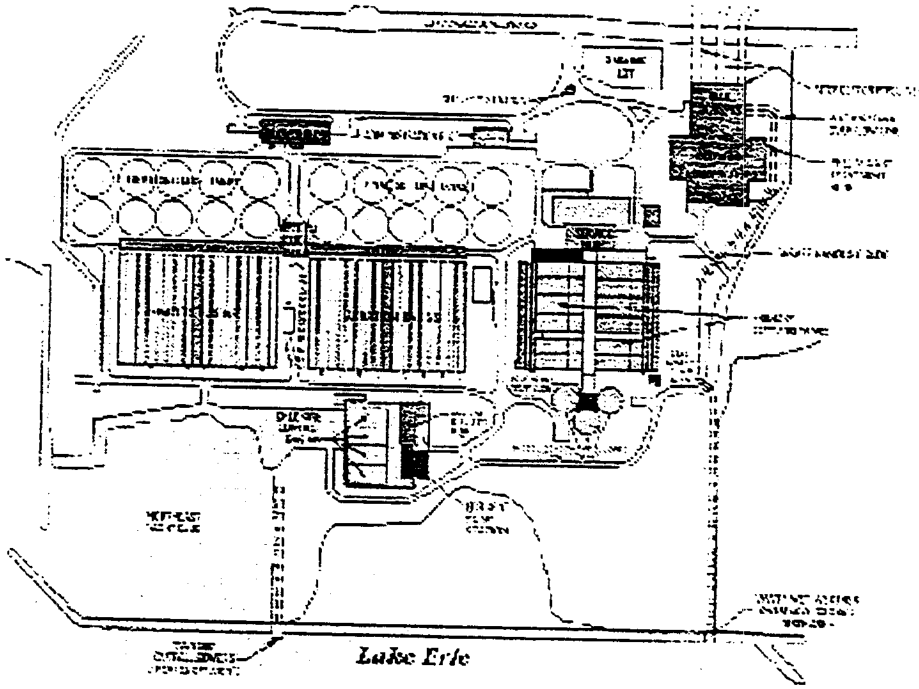

FIGURE 1. Easterly Wastewater Treatment Plant Schematic

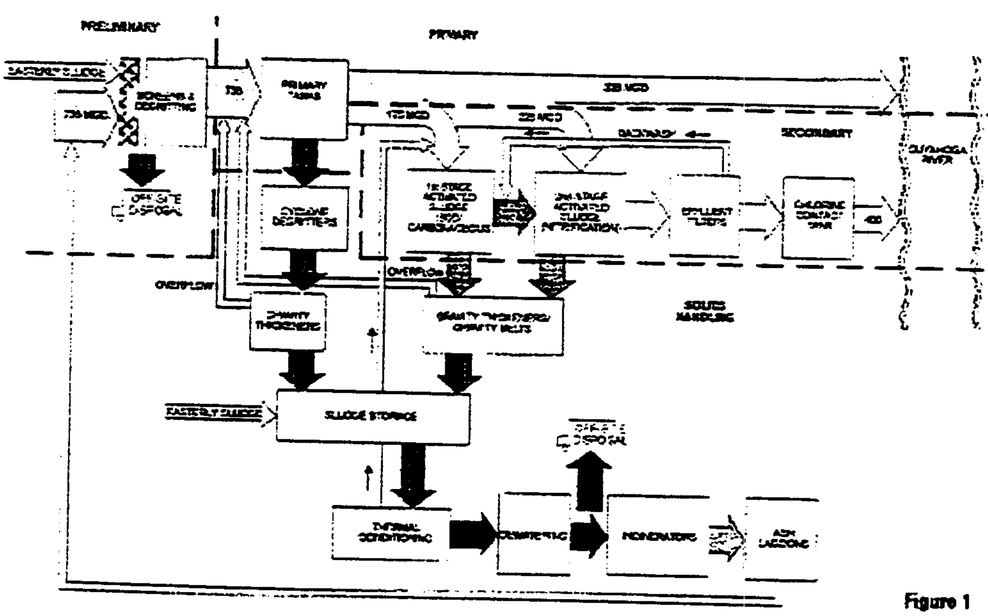

FIGURE 2. Southerly Wastewater Treatment Center Schematic

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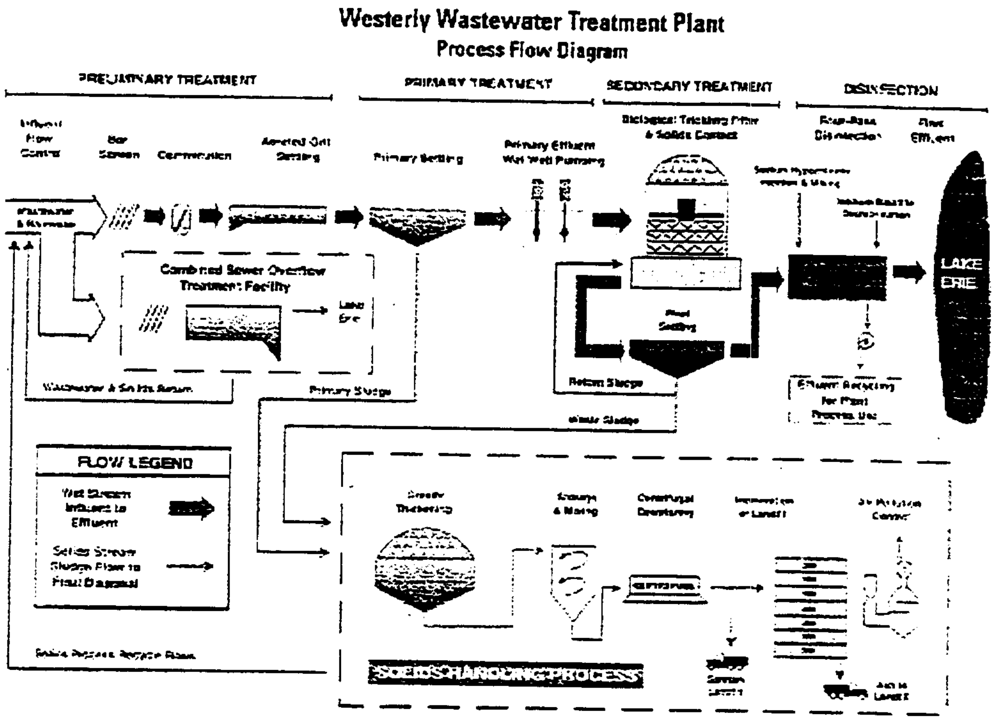


FIGURE 3. Westerly Wastewater Treatment Plant Schematic

Advances in Urban Wet Weather Pollution Reduction -- Cleveland 1998 Conference
The Northeast Ohio Regional Sewer District Wet Weather Programs
Session 4 (9:00 am - 12:00 pm)

Daniel M. Hudson
Manager of Systems Operation and Maintenance

In-line Storage of Wet Weather by Real-Time Control (9:30 am - 9:45 am)

Early on the Northeast Ohio Regional Sewer District (District) recognized the need for combined sewer overflow abatement. As early as 1972 the District constructed in-line storage devices that regulated the flow through three combined sewer regulators. The system included twelve rain gauges and twelve sewer level gauges. Monitoring and control was performed with a centrally located minicomputer. Control algorithms were calculated with one central computer and transmitted over dedicated data lines for remote control. The reliability of this system depended on the telephone lines, power service, and computer trustworthiness. By 1990, the District constructed 29 automated regulator, 25 rain gauges, 37 remote level monitors, and 50 remote flow monitors. Majority of the equipment was designed for distributed control with programmable logic controllers (PLC). Personal computers distribute information on a local area network (LAN) through a Supervisory Control and Data Acquisition (SCADA) system. Collection system information, such as wet weather flows, rain intensities, and systems levels, are delivered to the treatment plants in real-time. Plant operators make process control decisions based upon the sewer system data.

Each automated regulator has been constructed at an existing overflow regulator chamber or at a newly constructed chamber that was created by consolidation of several regulators. At each site a hydraulically operated knife gate, plug valve, or in-sewer timber gate controls the amount of flow in the dry weather pipe. Where possible, the size of the dry weather outlet pipe was increased to allow greater flow to be delivered to the interceptor. Fixed weirs were replaced with either an inflatable dam or a hydraulically operated bascule gate. Sewer levels upstream and downstream of the automated regulator are measured with bubbler level sensors. At some automated regulators, interceptor levels remote to the site are telemetered to the local controller. All control equipment is typically contained in a prefabricated underground control vault. The vaults contain support equipment for the automated regulators, including level and flow sensing systems, hydraulic systems, pneumatic systems, motor control panels, uninterruptibal power supplies, and a programmable logic controller.

During the design and construction of the real time control system, consideration was given to controlling the largest amount of combined sewage with the smallest number of automated regulators. The 29 automated regulators eliminated approximately 80 fixed weir regulators. Pipes were constructed that collect water from several regulators and direct the flow to one point where flow could be controlled and storage in the system. The 29 automated regulators control nearly one-quarter of the total flow from the 500 regulators in the Cleveland area. This is equivalent to preventing about 2 MGD of flow from entering the environment untreated every day.

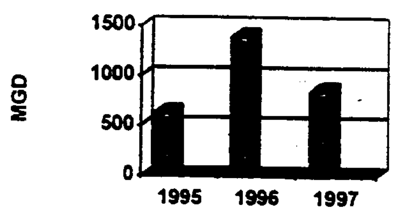
The District's experiences in real time operation and maintenance of a CSO facility are not unusual when compared to other organization with similar systems. Problems with inflatable dams started with the original construction over 20 years ago. Most problems stemmed from the original design and construction. The failure rate of the dams is currently approaching 50 percent total. The majority of the problems with the dam revolves around substandard design and installation. Most of the dams are manufactured with seams. Seam separation is the most common failure mode. Incomplete vulcanization from the original manufacturing process appears to be the major factor for seam separation. The original anchor design was a complicated system of rods, anchors and fabric. Improper installation of anchor bolts and placement of the fabric under the clamping rods has also led to some of the dam failures.

The District has currently replaced six of the original seam-type dams with a seamless design. The new design has proven to be reliable. The seamless dams have been in-service for about five years with no failures. The anchors for the seamless dams are a simple clamp that is mounted to the sewer walls by anchors imbedded in epoxy adhesive.

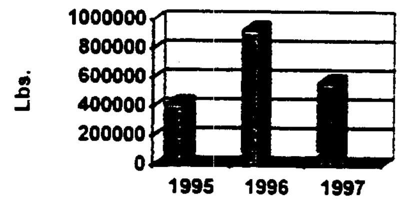
The annual operating and maintenance cost for each automated regulator annual cost is about $11,000. This includes all of the labor and material expenses required for preventive and breakdown maintenance. Capital cost and the original design and construction cost are not included. Each rain gauge costs about $2,600 per year to operate and maintain. The flow and level monitors cost about $3,000 each per year.

Less then one percent of the total capital expenditures for the District was used for the construction of the in-line storage system. Even with such small capital expenditures, in-line storage of CSO's has proven important in the reduction of overflows and resultant pollution loads to Lake Erie. Experiences at the District have shown that with intelligent design and construction, deliberate management, and maintenance, in-line storage can be environmentally effective and cost efficient.

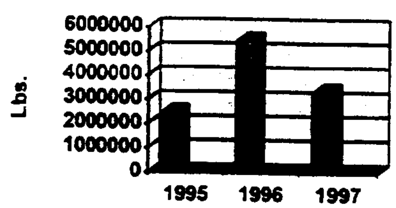
Stored - Combined Sewage



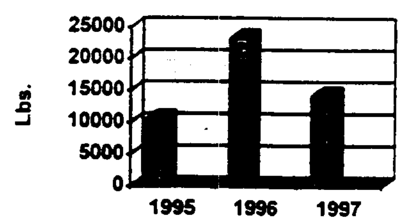
Captured BOD



Captured - Total Suspended Solids



Captured - Phos



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COMBINED SEWER SYSTEM BEST MANAGEMENT PRACTICES

Robert Gow, Northeast Ohio Regional Sewer District

The Northeast Ohio Regional Sewer District's (District) Wastewater collection System is as diverse as the people who populate the District's two-hundred ninety-five (295) square mile service area.

The District currently owns and/maintains two-hundred and seven (207) miles of intercepting sewers. These interceptors are located primarily within the boundaries of Cuyahoga County. One-hundred fifty-two (152) miles of these sewers are greater than forty-eight (48) inches in diameter, many of which were constructed in deep tunnels. The remaining fifty-five (55) miles of sewers are less than forty-eight (48) inches in diameter and were primarily open trench construction. One-hundred and two (102) miles of interceptors are less than thirty (30) years old and fabricated with reinforced concrete pipe. Brick sewers comprise the remaining one-hundred and five (105) miles of interceptors. These brick sewers range from fifty (50) to over one-hundred (100) years old. The average manhole depth of the old existing interceptors is twenty (20) feet. Whereas, some of the new deep tunnel interceptors exceed two-hundred (200) feet in depth.

The District also maintains four-hundred sixty-seven (467) Combined Sewer Overflows throughout Greater Cleveland. These are the fixed weir-type regulators of which there are four (4) styles in the Cleveland area:

- Perpendicular Weir
- Side Channel Weir
- Leaping Weir
- Relief Pipe

The leaping weir regulator is uncommon throughout the United States and seems to be unique to Cleveland. Historical data also reveals an increased susceptibility for maintenance problems at this type of regulator.

In addition to interceptors and regulators, the District assumes maintenance responsibility for nineteen (19) bar racks, twenty-eight (28) drop pipes, one-hundred twenty-five (125) permitted outfalls, twenty-four (24) miles of storm water outlets from regulators, and other sewer related appurtenances.

The District differs from other sewer authorities in the United States. Unlike other agencies, the District does not maintain the small local sewers. Each community maintains their own sewer system or has entered into a maintenance agreement with the Cuyahoga County Sanitary Engineers.

Inspection and maintenance of the District's Collection System is the responsibility of the Sewer Maintenance and Repair Section. This group includes eight (8) Field Technician Operators, who normally operate the sewer cleaning and inspection equipment, and routinely function as crew leaders also. The operators are supported by sixteen (16) Field Technicians who aide with equipment set-up, traffic control, and assist with actual cleaning and inspection activities. Two (2) supervisors and a manager complement the group. An additional supervisor is slated for later in 1998 (see Table 1).

The Sewer Maintenance Department employs a variety of equipment and vehicles. The following is a list of inspection and cleaning equipment routinely used by the group:

- Three (3) Combination Machines (Jet Vacs)
- One (1) Jet Truck
- Two (2) C.C.T.V. Trucks
- One (1) Easement Machine
- One (1) Manlift System
- Twelve (12) Inspection/Companion Vehicles
- One (1) Set Bucket Machines
- Miscellaneous gas/electric/air/hydraulic power tools

The Sewer Maintenance and Repair Section's goals and priorities are to maintain an unrestricted flow of wastewater to the District's Wastewater Treatment Plants, and to ensure against any dry weather discharges to the environment. These tasks are accomplished through the implementation of an aggressive inspection and maintenance program by skilled and dedicated District personnel.

Regulator maintenance is a priority item at the District. The four-hundred sixty-seven (467) regulators have been compiled into a set of inspection route books based on drainage area, eight by receiving waters or interceptors. The regulators are inspected at least twice per month. Regulators that exhibit a history of maintenance problems have been collected into a set of four (4) trouble-spot route books and are inspected weekly. A routine inspection crew consists of two (2) or three (3) technicians, depending upon the route book being inspected. Normally, three (3) inspection crews are in the field on a daily basis. To further enhance our inspection/maintenance program, a straight jet truck with a two (2) man crew inspects troublesome regulators on a daily basis. Preventive maintenance is performed at each site as necessary.

During the course of the work day, should an inspection crew encounter a blocked regulator, it is immediately reported to a Sewer Maintenance supervisor via two-way radio. The supervisor will then dispatch a jet vac to the site to relieve the blockage. This process has dramatically reduced response time to clean a blocked regulator. Anytime a blocked regulator is discovered by District personnel, the Ohio Environmental Protection Agency is also notified of the dry weather upset condition via fax. A status report follows when the regulator has been cleaned.

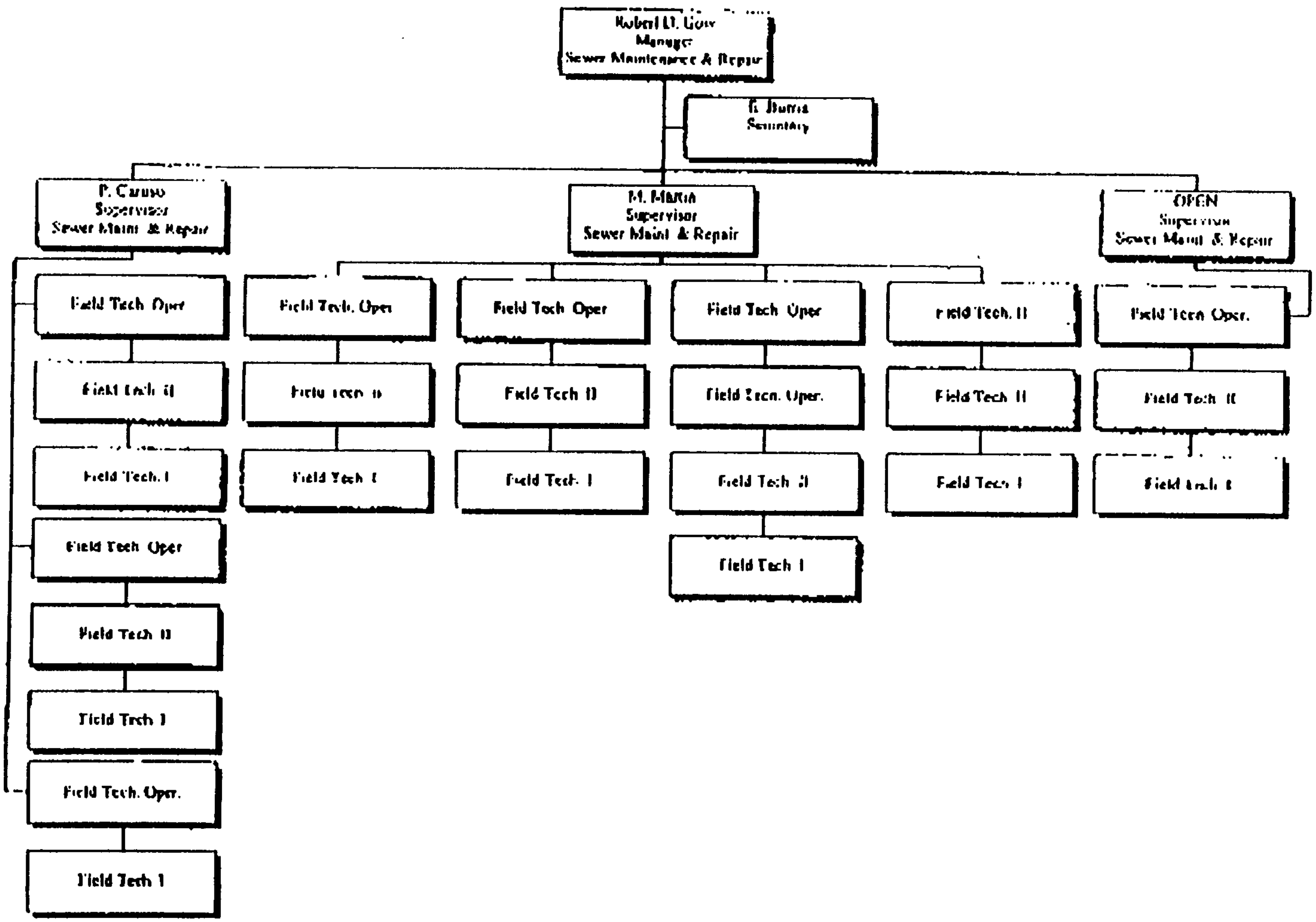
During 1997, District personnel inspected sixteen-thousand one-hundred and ninety-eight (16,198) fixed weir regulators (see Table 2). Total and partial blockages were removed at one-thousand six-hundred and forty-nine (1,649) sites (see Table 2). This intensive inspection/maintenance program reduced the number of chronic regulators, those that are blocked more than three (3) times per year, to four (4) (see Table 2). Further, the number of inspections it requires to locate a blockage increased to 265, compared to 87 in 1992 (see Table 2). Response time, the actual time to relieve a blocked regulator from the time it was reported to supervision, has been reduced to a little over an hour. Only a few years ago, a twenty-four (24) hour turnaround was the norm.

Looking to the future, the District will continue to pursue its goal to reduce dry weather overflows by incorporating new technology into the daily routine of sewer maintenance operations. Bar codes, commonly used in grocery/department stores, are now being used by District Sewer Maintenance personnel to inspect regulators. The District initiated a pilot program in early 1998 by which seventy-one (71) regulators are being inspected with the use of bar codes. The bar code system eliminates handwritten inspection/maintenance reports currently being used by the field crews. Bar code readers are downloaded into a computer at the end of each work day. The computer, in turn, logs each inspection and generates an inspection and maintenance report. Thus, increasing the number of yearly regulator inspections.

By years' end, the maintenance department intends to inspect the remaining regulators with the bar code system. Eventually, this program will be expanded to include bar racks, drop pipes and other general sewer maintenance activities.

TABLE 1

Northeast Ohio Regional Sewer District
Sewer Maintenance & Control



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FIXED WEIR REGULATOR STATISTICS

1. Total Number of Inspections
   1992: 10,867
   1993: 14,270
   1994: 14,359
   1995: 17,686
   1996: 19,723
   1997: 16,189

2. Total Number of Preventive Maintenance Activities
   1992: 1698
   1993: 1804
   1994: 2480
   1995: 2103
   1996: 2205
   1997: 1649

3. Number of Inspections to identify a Dry Weather Overflow
   1992: 87
   1993: 134
   1994: 138
   1995: 230
   1996: 238
   1997: 265

4. Time to Unblock a Regulator
   1993: Approximately 24 hours
   1994: 40% in 24 hrs; 60% less than 2 hours
   1995: 83% in 2 hours
   1996: 87% less than 2 hours; none exceeds 24 hours.
   1997: 1.32 hours

INTERCEPTORS & BIOFILTERS

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INTRODUCTION

Like many of the older Metropolitan areas in the country, the wastewater collection system for Greater Cleveland is comprised of both separate sanitary sewers and combined sewers. A master sanitary interceptor plan was initiated in 1966 to minimize pollutant overflows into Lake Erie and tributary streams.

One of the primary goals of the master plan was to intercept separate sanitary sewer flow for priority treatment at the wastewater treatment plants, thereby:

- Reducing separate sanitary overflow (SSOs) into environmentally sensitive urban streams and lakes.
- Reducing flows to the combined sewer areas thereby reducing the volume and frequency of combined sewer overflows (CSOs).

Two interceptor systems were eventually designed and constructed as a result of the master plan. They are the Southwest Interceptor and the Heights/Hilltop Interceptor. Together these two projects consist of 50 miles of interceptor sewers which service over 500,000 people at a cost of $242 million. The first part of this paper will focus on one segment of the aforementioned interceptors, Hilltop Interceptor Contract G, from design through construction.

DESIGN

The design of the Contract G was based on a five year, one hour storm event. Initial design concepts included the consideration of a new surface storage facility consisting of a concrete lined detention tank. However, the concept of a storage-conveyance tunnel proved to be more economical. However, due to the depth of the tunnel, it is feasible to construct additional detention tanks next to the interceptor should the need for expansion be identified in future studies.

OVERFLOW STRUCTURE

The concept for the overflow structure was based on characteristics of a typical detention basin's outfall structures used for surface drainage systems:

1. Control outlet discharge rate by an orifice device.
2. Provide an overflow weir to allow for controlled discharge of flows exceeding the design rate.

However, early in the design stage, it was recognized that to design an outlet control device operating under 105 ft. of a hydrostatic head and discharging into the existing tunnel would require hydraulic modeling. An empirical design approach was considered too risky without guaranteed performance results for the $750,000 structure. The critical issue was to assure stable overflow conditions and still provide acceptable flow characteristics in the shaft and the downstream tunnel.

The design was initiated on a system that would detain incoming flows in the tunnel by controlling the outlet rate through a small diameter pipe (the throttle pipe) at the overflow structure. When the incoming flows exceed the outlet discharge, the water level continues to rise, utilizing the tunnel as a detention tank, until the outlet rate exceeds the inflow rate, at which time the storage in the tunnel is depleted.

From the flow monitoring data which was incorporated into the SWMM program, a hydrograph of the design storm was developed to calculate the size, depth and profile of the tunnel, length and size of the throttle pipe and the volume of the desired storage capacity. Once the system was sized, the data, along with conceptual construction details were sent to the Iowa Institute of Hydraulic Research (IIHR) for modeling. As a result of the IIHR modeling, a smaller diameter throttle pipe was incorporated into the system to decrease its length. A reducer was added to the end of the throttle pipe, in the opposite direction of the flow, with a short larger diameter pipe at the terminus of the throttle pipe to reduce the existing flow velocities.

The IIHR also studied the shape and width of the overflow weir to produce stable flow conditions in the event that the design storm runoff rate is exceeded or the throttle pipe becomes clogged. The modeling concluded that during the worse case conditions, about 4 ft. of flow would over top the weir within the overflow structure shaft. The study also concluded that baffles to control the existing velocities were not needed. The findings from the IIHR modeling were incorporated to finalize the geometry of the full scale structure.

CONTRACT G SYSTEM

When the design of the interceptor was completed, the Contract G system comprised of approximately 11,750 ft. of 132 in diameter storage conveyance tunnel at a slope of 1.00% with 174 ft. of 33 in. diameter throttle piping with reducer and 10 ft. of 36 in. diameter outlet pipe. The system has a peak discharge rate of 145 mgd. (reduced from 285 mgd.) and a storage capacity of 6.5 million gal. The discharge from the throttle pipes and the overflow weir is directly into a downstream tunnel completed under previous contracts. Three access shafts, one deaeration chamber, two work shafts, drop pipe and access adit complete the Contract G system.

ACCESS AND WORK SHAFTS

The NEORSD Maintenance Department has a preference that for large diameter interceptors, the spacing between the access shafts or manholes should not exceed 3,000 ft. This distance is set by the safety equipment reach capacity, such as winches, cables and emergency breathing air packs. Also, at this spacing, ventilation of the system can be accomplished in reasonable time prior to the entry of personnel into the tunnel.

This spacing requirement, at times, positions an access shaft in an area where available land is limited, not available or the surface access shaft covers are in the street and/or roadway with heavy traffic. This was the case on the Contract G requiring the designers to utilize an offset access shaft arrangement. In addition, maintenance access to the tunnel is provided by the NEORSD through the use of a Maintenance Trailer operating from the surface. The trailer has a man-cage which allows personnel to be lowered and picked up directly form the shaft inverts (at tunnel level) and allows for air testing equipment to be lowered to the tunnel level prior to the entry of personnel. The cage can also be used to lower air testing monitors any other safety or support equipment.

CONSTRUCTION

The final bid package consisted of detailed design for shafts and tunnel (final and initial excavation supports), shaft sites, site restorations, details, geotechnical report and other information necessary to complete the package. The contract was bid on in November of 1990 with KM&M, Joint Venture as the successful contractor. The low bid amount was $16,084,517.00.

Shaft excavation utilized a vertical boring machine (VBM) and drill and blast methods. The VBM was developed by the Kassouf Company of Cleveland, Ohio based on designs used in previous NEORSD projects. The machine was capable of excavating downward into the shales and other soft rocks. The two stage cutter head moved rock cuttings toward the center, where they were lifted by a vertical auger to a skip for hoisting to the surface. As the machine excavates downward, the shaft's initial supports were installed from the VBM's platform.

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The tunnel boring machine (TBM) selected was built by Lovat Tunnel Equipment, Inc. and came equipped with drag cutters and a rear thrust ring requiring ribs and lagging as thrust reaction. The excavation of the main tunnel started on September 6, 1991 and was completed on February 11, 1992. This resulted in a total of 158 calendar mining days (or 162 mining shifts). The following is the summary of the TBM mining record for the project:

Average feet per shift (beginning 9/6/91)		71.60
Average sets of ribs and lagging installed per shaft		17.30
Total footage mined		11,671.96
Total calendar days		158
Total mining shifts		163
Highest footage mined - one shift	11/11/91 (1st shift)	115.70
Highest footage mined - one work day	12/20/91	223.50
Highest footage mined - one work week	12/02/91 thru 12/06/91	931.60

The adits for the access shaft and the deaeration chamber were excavated by a smaller TBM without any trailing gear to avoid drilling and blasting. After the excavation, reinforcing steel was placed in the adits and dearation chamber, followed by the placement of concrete.

The final lining in the tunnel was cast utilizing a 210 ft long form. The average daily placement was 180 ft utilizing with 300 cy. of concrete. The placement started at the upper limit of the tunnel profile. Cleaning of the invert, reinforcement placement and rail removal was performed ahead of the concreting operation. Forms were stripped when concrete lining reached 1,000 psi. After the concrete reached its full strength, contact grouted was employed in the crown area.

For the overflow structure, shaft, and outfall sections of the tunnel (throttle pipe), the final lining concrete mixture contained microsillica. The microsilica additive produced concrete with an average strength of 7,500 psi that was of a higher density and resistant to abrasion.

The throttle pipe consisted of DIP piping, anchored down with reinforcing steel to the final lining and was completely encased in concrete.

CONCLUSIONS

The Contract G proved to be a very successful tunnel project. The geotechnical conditions and initial support type requirements were predicted during the design stage. The construction on the project was authorized to proceed on January 9, 1991 with the completion deadline of June 22, 1993. The actual completion was on December 1, 1993. The delay resulted from a change order requiring the Contractor to dispose of the rock muck saturated with natural oil in the same manner as hazardous waste. The muck was tested and the disposal locations were documented.

The original bid price was $16,084,517. The final cost of the project was $16,225,741. Total extra work on the contract amounted to $905,039 and the total deductions were $763,814, this resulted in a net increase to the contract bid price of 0.88 percent.

BIOFILTERS

INTRODUCTION

Initial flow into portions of the HHI and the SWI began in 1991. When these minor (10 percent of design) flows were diverted into the tunnels several years ago, the District immediately began to receive odor complaints. At first, the problems were relatively minor and were attributed to low flow conditions. District personnel corked certain manhole lids to alleviate local odor problems and the odor complaint issue was considered solved. However, during the summer of 1995, when more flow was introduced into the upstream portion of the system, odors became much more prominent and widespread.

When it was recognized that the odor problems were a direct result of increased flow and that the problem could not be solved by corking manhole lids, the District immediately moved forward to investigate the problem and find a solution. The goal of the investigation was to understand the cause and extent of the tunnel odor release problem, evaluate alternatives to solve the problem, select the appropriate technology and retrofit the system with the most reliable odor control facility possible. Because the probable locations of any odor control facilities would be remote sites in the collection system, the District recognized that one of the most important aspects of the selected treatment system would be operation with minimal operator intervention.

INVESTIGATION

The investigation found that both the HHI and SWI tunnel systems were being pressurized by the eduction of air through the drop shafts. The amount of air educted varied with the quantity of wastewater being dropped and the size and shape of the drop structure. When the wastewater flow down the drop pipe is low, surface tension holds most of the water against the wall of the pipe creating a large central air core . Little air is educted in this case. In fact, if the pressure in the tunnel is high enough, air will overcome the force of the downward draft in the vortex pipe and vent to the atmosphere through the large central air core. However, as the wastewater flow down the vortex shaft increases, friction increases, the central air core becomes smaller and the educted air pressure overrides the pressure in the tunnel. Therefore, as the wastewater flow down the vortex shaft increases, the amount of air being educted also increases.

The surface tension of water is another reason why increased wastewater flow down the vortex shafts causes greater air eduction forces. Under low flow, most of the wastewater falling down a vortex hugs the wall of the pipe. This is the effect of the surface tension of water. The wetted surface of the pipe acts as an anchor and the surface tension between the individual molecules of water act to keep the water from shearing and forming individual droplets.

As the volume of wastewater increases, surface tension forces are not strong enough to hold the water against the surface of the pipe and shear distorts the water surface in the form of wave fronts which travel down the pipe. This wave is the first indication that shear forces, induced by gravity, are overcoming the surface tension because the wave front travels faster down the pipe than the water next to the pipe wall.

When the flow down the vortex pipe becomes large, surface tension forces are only exerted for a short distance from the pipe wall and the rest of the water is in full hydraulic shear. As the droplets shear from the wall they fall like "rain" down whatever may remain of the central air core causing increased surface area upon which friction with the air can act. Under this condition maximum air is being educted down the vortex pipe.

EVALUATION OF ODOR CONTROL ALTERNATIVES

All feasible alternatives were considered for odor treatment or control on the HHI and SWI deep tunnel collection systems. The final recommendation was to employ biofilters.

Biofilters are a type of odor control system that adsorbs/absorbs and oxidizes odorous compounds using microorganisms growing in a soil or compost substrate. Biofilters are successful in treating hydrogen sulfide, ammonia, organic odors and volatile organic compounds from municipal wastewater treatment plants and pump stations, composting facilities, rendering plants, and other solids processing facilities. Odors are absorbed into a thin water film surrounding the substrate particles and also adsorbed directly on to the particles. The sorbed compounds are then metabolized by bacteria and converted to sulfite or sulfate, carbon dioxide, ammonia and water. This oxidation step frees the sorptive sites for additional odorous compounds, thereby continuously regenerating the biofilter.

Biofilters have been used to treat hydrogen sulfide in wastewater collection and treatment systems in the United States since 1959. Their increasing popularity is due to the simplicity of the system, lack of intensive mechanical equipment, and the use of no treatment chemicals. Biofilters have gained acceptance in recent years with more research and full-scale operating experience. The major components of a biofilter system include a fan for transfer of odorous air to the biofilter, a distribution system consisting of a header/lateral piping network and distribution plenum, and the substrate. Usually, biofilters also require an irrigation system and a humidifying system to maintain moisture content of the substrate.

Influent air must be evenly distributed across the entire area of the biofilter for optimal treatment. Failure to achieve uniform distribution may result in localized channeling through the substrate, unequal contaminant loading, odor breakthrough, and development of high headloss with a corresponding drop in airflow. The most basic and commonly used distribution system consists of PVC headers with perforated laterals in a silica stone gravel bed. Some installations have used manufactured blocks to achieve uniform distribution, however, these systems are proprietary and not commonly used.

The biofilters will be conservatively sized using a loading rate of 3 to 4 cfm/sf and a headloss of 6 inches. The depth of the biofilter will be 3 ft and will consist of yard and sludge compost and shredded bark. The treatment bed will be about 85 feet long and 25 feet wide. Maintenance costs will include periodic replacement of the substrate. Capital and O&M will be relatively low, approximately $0.6 million, for one biofilter. Six biofilters are the projected need for the HHI and 5 biofilters on the SWI.

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BRICK MASONRY SEWER REHABILITATION USING SLIP LINE METHOD

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ABSTRACT

Slip lining circular brick sewers involves inserting a slightly smaller pipe section inside the existing sewer. The annular space left between the new liner pipe and the host sewer is filled with grout. Lateral and side sewer connections generally must be excavated and reconnected to the new liner from the exterior of the existing sewer. The method is most practical for sewers of circular cross section in reaches where there are few existing lateral connections. Slip lining can maintain the structural integrity of the existing brick sewer and improve the hydraulic capacity of the sewer even though the finished diameter has been reduced.

INTRODUCTION

All sewer collection systems require constant maintenance. With time, all structures deteriorate, and circular brick masonry sewers are no exception. The objective of all sewer rehabilitation is to maintain the viability of the conveyance conduit and this is accomplished by (1) ensuring its structural capability, (2) reducing infiltration and inflow (I/I), and (3) controlling exfiltration. The selected rehabilitation method will depend on the rehabilitation objectives and a cost vs. benefits analysis. Most structural rehabilitation methods provide for a reduction in rates of I/I, however, most infiltration control rehabilitation measures have very little impact on enhancing structural integrity. A proper and thorough evaluation of sewer defects is paramount in determining the appropriateness of a given repair method. The selected rehabilitation measure should be chosen for its ability to best correct the cited defects.

CRITERIA FOR REHABILITATION

The structural integrity of a circular brick masonry sewer relies on the support of the surrounding soil. Regardless of its cross section, the crown of a brick masonry sewer is a semicircular arch. This arch behaves as a compression ring supporting vertical loading from above and the lateral loading of the backfill soils at the sides of the sewer. If voids in the backfill material develop near the sewer's springline, lateral support is lost and the sides of the arch can move outward under the weight of the soils above the crown. Void development is associated with soil displacement due to groundwater. Fine granular backfills can be "piped" inside the sewer through cracks, open mortar joints, or poorly made lateral connections. This mechanism will cause the crown to flatten and crack. When vertical deflections of the crown develop and achieve at least a 10% reduction in height, the sewer is considered to be at risk of structural failure. Mortar loss through erosion or sulfite attack from sewer atmospheres can result in displaced or missing bricks which can eventually lead to collapse. Infiltration problems can develop into mineral deposits, deposition of debris in the invert, dropped inverts, and loss of hydraulic capacity. Invert debris can alter flow velocities causing excessive wearing of the invert surface. Cracks, fractures, and holes can allow the undesirable development of exfiltration of sanitary flows to the environment.

THE WESTERLY INTERCEPTOR: A CASE HISTORY

The advance of time has not been kind to the old brick masonry combined sewer known as the Westerly Interceptor owned by the Northeast Ohio Regional Sewer District. The age of the sewer is estimated to be approximately 80 to 100 years old. Several existing conditions, such as periodic surcharging and the proximity of its alignment to a heavily used rail line , have lead to advancing its deteriorated condition beyond its years. In August of 1994, after an unusually heavy rainfall event, a twenty foot long section of 87-inch diameter sewer collapsed forcing emergency cast-in-place concrete repairs totaling upwards of two hundred thousand dollars.

In September of 1995, the District once again paid a contractor to mobilize on an emergency basis to replace a 150 foot long reach of 90-inch brick sewer with reinforced concrete pipe of similar size. This effort resulted in costs totaling more than six hundred thousand dollars. While replacement of damaged or severely deteriorated sewer sections is totally effective in meeting the objectives of sewer rehabilitation, the cost of performing work utilizing replacement methods is staggering. The District's recent experiences with the Westerly Interceptor focused its attention on adopting a preventive maintenance approach. Consultants were hired to study and assess the structural condition of the Westerly Interceptor. The reach of sewer to be evaluated is approximately a 4,000 foot long section located along and parallel to the Conrail railroad tracks beginning at Lake Avenue and continuing in a northeasterly direction to W. 65th Street and Father Caruso Drive on the near west side of the City of Cleveland. Its size ranges from five foot in diameter at the western end to eight foot in diameter at the eastern end.

A sewer stability assessment report prepared by Woodward-Clyde Consultants in July of 1995 arrived at several conclusions after observing defects evident in visual inspections performed specifically for the study, and these are listed as follows:

- Inner brick ring mortar matrix has deteriorated to a point that will promote more rapid ring delamination
- Delamination of the crown brick is decreasing sewer cross section
- Brick loss indicates deterioration of middle brick ring
- Structural integrity of the sewer is being compromised as a result of further mortar matrix deterioration

In May of 1997, the consulting engineering firm, Brown & Caldwell , released the findings of their localized geophysical investigation on the same reach of sewer. Seismic resonance testing (SRT) indicated potential areas of void in the backfill soils surrounding the sewer. Identifying areas containing significant amounts of void within the surrounding backfill provides information about confining earth pressures and the ability of the sewer to capably support or resist the stresses imposed by existing service loadings. Their findings and recommendations are listed as follows:

- The proximity of the interceptor to the railroad tracks and the associated high levels of ground vibration increases the potential for soil migration through existing defects in the sewer and the potential for future collapses
- The general area of the sewer in the region of the 1994 collapse should be strengthened using grout piles or other soil grouting techniques
- Cracks, fractures, and deformations in the sewer reach between manhole(MH)65 to MH60 should be corrected and the soil surrounding the sewer in this region should be strengthened with grout
- Brick sewers with cracks, fractures, and other physical defects are under obvious distress and are subject to catastrophic collapse, especially sewers where surcharging can occur
- Rehabilitation of the sewer only (i.e. relining without adding structure) is insufficient in these areas since the surrounding soils lack the required strength to support the brick sewer

Loss of confining soil pressure, surcharging flows and external vibration loadings (due to heavy rail traffic) continue to add to the distress of the Westerly Interceptor. Loss of mortar due to aggressive sewer atmospheres and external groundwater pressures promotes movement and delamination of brick, leading to further loss of arch compressive strength of the crown. Mortar loss is occurring throughout the entire length of the Interceptor study area to varying degrees and is a function of exposure time to acidic sewer atmospheres and groundwater fluctuations.

SELECTION OF SLIP LINING AS THE REHABILITATION MEASURE

If elimination of significant void development in the backfill soils around the outside of the sewer is a primary objective, then lateral support of the crown arch can be maintained, thus preventing the flattening and cracking of the arch due to vertical loading from the weight of soil above the sewer's crown. Another objective in maintaining the strength of the section would be to mitigate surcharge conditions that occur due to wet weather events. This is significant in areas where voids in the backfill have already developed due to piping diminishing the compressive stress developed within the arch. Steadily increasing internal pressures during surcharging can counteract the dead load compressive stress and cause the brick/mortar matrix of the arch to develop tensile stresses which is very undesirable. The reality is that certain storm events will produce some surcharge conditions somewhere within the system. The practical approach to meet the objective of maintaining strength during these events would be to minimize the internal pressures distributed to the brick/mortar matrix by installing a lining capable of supporting these stresses.

The current Westerly/Walworth Interceptor Rehabilitation project designed by Brown & Caldwell specified the use of a glass fiber reinforced thermosetting resin pipe material to be installed as a slip line within a 1,700 lineal foot reach of the Westerly Interceptor along the Conrail easement. The use of slip line pipe satisfied all project objectives by providing the necessary strength (for both external and internal loading), reduction of inflow and infiltrations, and mitigation of exfiltration of sanitary flow to the environment.

CONSTRUCTION PHASE SLIP LINE ACTIVITIES

To gain access to the sewer for slip lining, two access pits had to be excavated along the alignment. Coordination with the railroad was required during the design of the braced cofferdams and their installation. Within the pits, the crown of the sewer required careful removal from springline to springline for approximately a 21 foot length. Approximately 1150 linear feet of slip line pipe was installed by the contractor from the western most access pit by pulling the pipe material into position from each direction. Approximately 550 linear feet of slip line pipe was pulled into position utilizing the access pit at the eastern end of the project. The contractor, following an approved confined space entry and safety plan of his own development, accessed the sewer to assess existing conditions and make field verifications prior to ordering the slip line material for the project. All dry weather flow was diverted to another combined sewer on a parallel alignment and provisions were made to overpump flows from local side sewer connections.

The sewer was prepared for the installation by pressure washing the existing brick interior surface to remove slime, obstructions, and loose debris and also to enhance bond between the brick and the annular space grout to be pumped in behind the slip line pipe at a later stage. The contractor also took the opportunity to conduct the necessary pre-installation checks and verify cross-sectional tolerances. Two lines of light pipe rails were installed in the invert of the existing brick sewer to a tolerance established by the contractor's survey crews. The rail system was established to hold grade and assist in skidding the slip line pipe along the invert as it was pulled into place. Each twenty foot length of slip line pipe was winched into place by a crawler crane using a special pull ring with the cable running through the barrel of the pipe segment pulling the pipe back toward the cable drum of the crane. As pipe sections were pushed home, each piece was blocked with timber at the springline and crown and one intermediate point each side of crown center. The blocking was positioned to extend across the joint between pipe segments. The installed slip line sections were bulkheaded with concrete at manholes prior to grouting. All existing side sewer connections were reconnected from inside the existing Westerly Interceptor.

Slip line pipe does not require extraordinary strength to withstand external pressure from soil and groundwater, due to its structurally efficient circular shape. The condition critical to the design of the liner segment is the effect of the annular space grouting operation. If blocking is not properly placed, and the liner segment is buoyed upward by the grout, a concentrated load will develop along the crown of the segment, distorting the segment out of round. Additionally, the hydrostatic pressure exerted by the grouting procedure is likely to be greater than the hydrostatic pressure from groundwater, and will be acting on the liner pipe segment before the slip line has the circumferential support of the fully set grout. The contractor elected to use a light weight grout so as to minimize the buoyant force on the pipe segments. He also elected to grout in lifts to control the development of uplift forces. Displaced air and water venting, grout pressure monitoring and grout volume monitoring helped to provide for a successful installation. Grout coverage was verified through hammer soundings and discretionary drilling through the liner into the annular space. Patching was performed with fiberglass resin two-part mix.

CONCLUSIONS

The slip line pipe installed on the Districts Westerly Interceptor project was done so under what could be termed very favorable conditions. Costs were kept in line due to readily accessible sites, a minimum number of existing side sewer or lateral reconnections, and fairly straight reaches of sewer alignment. Unit prices bid for the slip lining of 1,142 L.F. of 84-inch and 87-inch diameter brick sewer with 66-inch inside diameter Hobas Pipe and 572 L.F. of 90-inch and 96-inch diameter brick sewer with 77-inch inside diameter Hobas Pipe were approximately $955.00 per L.F. and $1200.00 per L.F. respectively. These prices compared very favorably to open cut total replacement costs which could have approached several thousand dollars per foot of the same alignment due to the additional braced excavation costs required for work on railroad property.

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NORTHEAST OHIO REGIONAL SEWER DISTRICT CSO/WATERSHED PLANNING

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INTRODUCTION

The Northeast Ohio Regional Sewer District (District) service area contains both combined and separate sewered areas. Facilities planning in the separate sewered areas during the early 1980s resulted in a major separate sanitary interceptor construction program which is nearing completion. Essentially, this construction program has removed the separate sanitary sewer area's contribution to the downstream combined sewer area. Although substantial combined sewer overflow (CSO) reductions have occurred from this effort, significant CSO volumes remain uncontrolled.

The combined sewer system in the District's service area covers the majority of the City of Cleveland and a number of suburban communities. The combined sewer area covers approximately 50,000 acres and contains 125 CSOs. Each of the District's three wastewater treatment plants (WWTP), Easterly, Westerly and Southerly, have tributary combined and separate sewered areas. The District has an NPDES Permit for its CSOs which requires the completion of CSO control plans before 2002. To satisfy this permit requirement, the District has chosen to complete its CSO facilities plans in several phases. The following areas are being addressed:

- Mill Creek Watershed
- Westerly CSO District
- Easterly CSO District
- Doan Brook Watershed
- Southerly CSO District

Figure 1 outlines each of these planning areas.

FACILITIES PLANNING TASKS

In conjunction with or during each facilities planning project, the following tasks have been/are being performed:

- **Dry-Weather Outfall Surveys:** Every outfall within each study area is being located and sampled (if flowing) during dry weather. Outfalls showing appreciable bacterial contamination are being investigated for illicit connections.

- **Interceptor Inspection:** All District interceptors are being televised and internally inspected to assess condition, identify rehabilitation/cleaning needs and to verify flow connectivity.

- **WWTP Wet Weather Capacity Evaluation:** The wet weather capabilities of both the Easterly and Westerly WWTPs have been assessed prior to each applicable CSO facilities plan.

- **Community Sewer Flooding:** An assessment of community sewer flooding areas is being performed during CSO facilities planning. Where possible, coordination of community sewer flooding alleviation projects with CSO control projects is being sought.

- **Stream Flooding:** During both the Mill Creek and Doan Brook Watershed Studies, an analysis of stream flooding was incorporated into each project.

- **Macroinvertebrate Sampling:** Macroinvertebrate sampling programs are being performed to gauge the biological health of various receiving streams.

FACILITIES PLANNING AREAS - OVERVIEW

Mill Creek Watershed

In 1996, the District completed the first of its CSO planning projects in the Mill Creek Watershed area. Mill Creek is a small tributary to the Cuyahoga River and is located within the District's Southerly WWTP service area. The Mill Creek Watershed area contains separate, combined and common trench sewers. Twenty-eight (28) CSOs are located within the watershed and basement flooding is a problem throughout much of the watershed. Common trench separate sewer systems across the District's service area are in the over/under, separate manhole or common manhole/dividing wall arrangement, as shown on Figure 2. The common trench sewer system is particularly troublesome, as study results indicated that bacteria levels from the common trench storm sewers were comparable to CSO bacteria levels. Mill Creek currently does not meet Ohio EPA's primary contract recreation standard during dry and wet weather conditions.

A watershed approach was utilized to identify key dry and wet weather impacts in the study area. Key recommendations or findings of the study were:

- Construction of a storage/conveyance tunnel would serve as the backbone of an integrated approach to solve basin-wide issues, such as basement flooding reduction and CSO control.
- Community projects were needed to relieve wet weather sewer flooding problems.
- Elimination of illicit sanitary connections to storm sewers is needed.
- The high level of impervious area within the watershed (30%) appears to be the primary cause for non-attainment of the Creek's biological use designation.

Construction of the 20 foot diameter Mill Creek tunnel is ongoing. Once completed, CSO volume basin-wide will be reduced by over 90%, CSO frequency will be less than 5 CSOs/year at each Mill Creek CSO location and increased capacity (up to a 5-year storm) will be available to convey separate sanitary sewer flows.

Westerly CSO District

The second CSO planning project is currently ongoing in the Westerly CSO District. This planning area covers approximately 10,000 acres on Cleveland's west side, with 75% of the area served by combined sewers. Common trench sewers serve a large part of the remaining 25% of the service area. A number of the common trench sewer manholes have a removable plate in the invert of the storm sewer. This plate is removed to provide access for maintenance of the sanitary sewer which runs parallel to, but below, the storm sewer. Twenty-six (26) CSOs are located across this service area. Previous CSO control efforts in this area included the installation of 8 hydrobrakes and 8 automated regulators (inflatable rubber dams or hydraulic gates) for in-line storage of combined sewage. A storage/conveyance tunnel, known as the Northwest Interceptor, has been in operation since the 1980s. This tunnel stores CSO flows and releases these flows to a combined sewer overflow treatment facility (CSOTF) located adjacent to the District's Westerly WWTP.

CSOs in the Westerly planning area discharge to Lake Erie, Big Creek, Rocky River and the Cuyahoga River. A public swimming beach is located along Lake Erie within the project area. Due to the large size of the drainage areas of these receiving waters (both the Rocky and Cuyahoga Rivers have significant drainage areas outside of the District's service area), the level of detail in "watershed assessment" is not as great as that employed during the Mill Creek project. The Westerly CSO study is scheduled for completion near the end of 1998. Currently, computer modeling and alternative evaluation activities are ongoing. Key findings of the study to date are:

- Rising Lake Erie levels (near all-time records) have caused backflow of the Cuyahoga River into the District's interceptor system. River inflow control facilitates are under design.

- Numerous invert plates in the common trench system were either missing or misaligned. Computer modeling activities will determine the benefits of invert plate correction.

Easterly CSO District

In early 1998, two CSO facilities planning projects were initiated in the District's Easterly WWTP combined sewer area. The first, known as the Easterly District CSO Study, covers the entire Easterly CSO area. This study area covers approximately 15,000 acres of combined sewer service area and contains forty-six (46) CSOs. CSOs discharge to Lake Erie, the Cuyahoga River and numerous smaller urban streams and culverts. A public swimming beach is located along Lake Erie within the project area. Although the construction of the District's Heights/Hilltop Interceptor will reduce system CSO volumes by a projected 500 million gallons annually, significant CSO volumes will remain. As in other CSO planning areas, a mix of combined, separate and common trench sewers exist in the study area. Project completion is scheduled for 2000.

Doan Brook Watershed

Within the overall Easterly CSO Study area boundary lies the Doan Brook Watershed. The Doan Brook Watershed encompasses a total area of approximately 8,000 acres, with 4100 acres served by combined sewers. Sixteen (16) CSOs are located along Doan Brook. The Doan Brook Watershed Study was initiated in early 1998 and is expected to be completed by 2000. In addition to traditional facilities planning tasks, a comprehensive assessment of watershed problems and pollutant sources will be performed. Analysis of stream flooding characteristics will occur, as flooding exists in the lower portion of the Doan Brook Watershed. A U.S. EPA demonstration grant is funding a portion of this watershed project.

Southerly CSO District

The final District CSO facilities planning study is scheduled to begin in 1999 in the Southerly WWTP combined sewer area. This planning area encompasses approximately 17,000 acres of combined sewer area and contains twenty-five (25) CSOs. The Cuyahoga River and Big Creek receive CSO discharges from the Southerly study area, although each of these receiving waters have large upstream tributary areas.

SUMMARY

The development of CSO control facilities plans across the District's combined sewer service area is an ongoing task scheduled for completion in 2002. A total of five separate studies are being performed to complete the District's long-term planning for CSO control. In certain urban watersheds within the District's service area, detailed watershed assessments are being performed. Each facilities plan will result in the identification of recommended CSO control projects (which is the District's responsibility to implement) and recommended community-based projects (to alleviate flooding). Currently, the District does not have direct jurisdiction over separate storm drainage within its service area. Therefore, required projects to alleviate storm flooding or quality (illicit connections) problems are the responsibility of the applicable affected community. A District program known as the Community Discharge Permit Program is used to manage community-based projects. Details regarding this program can be obtained by referring to the discussion provided by Jeffrey E. Duke.

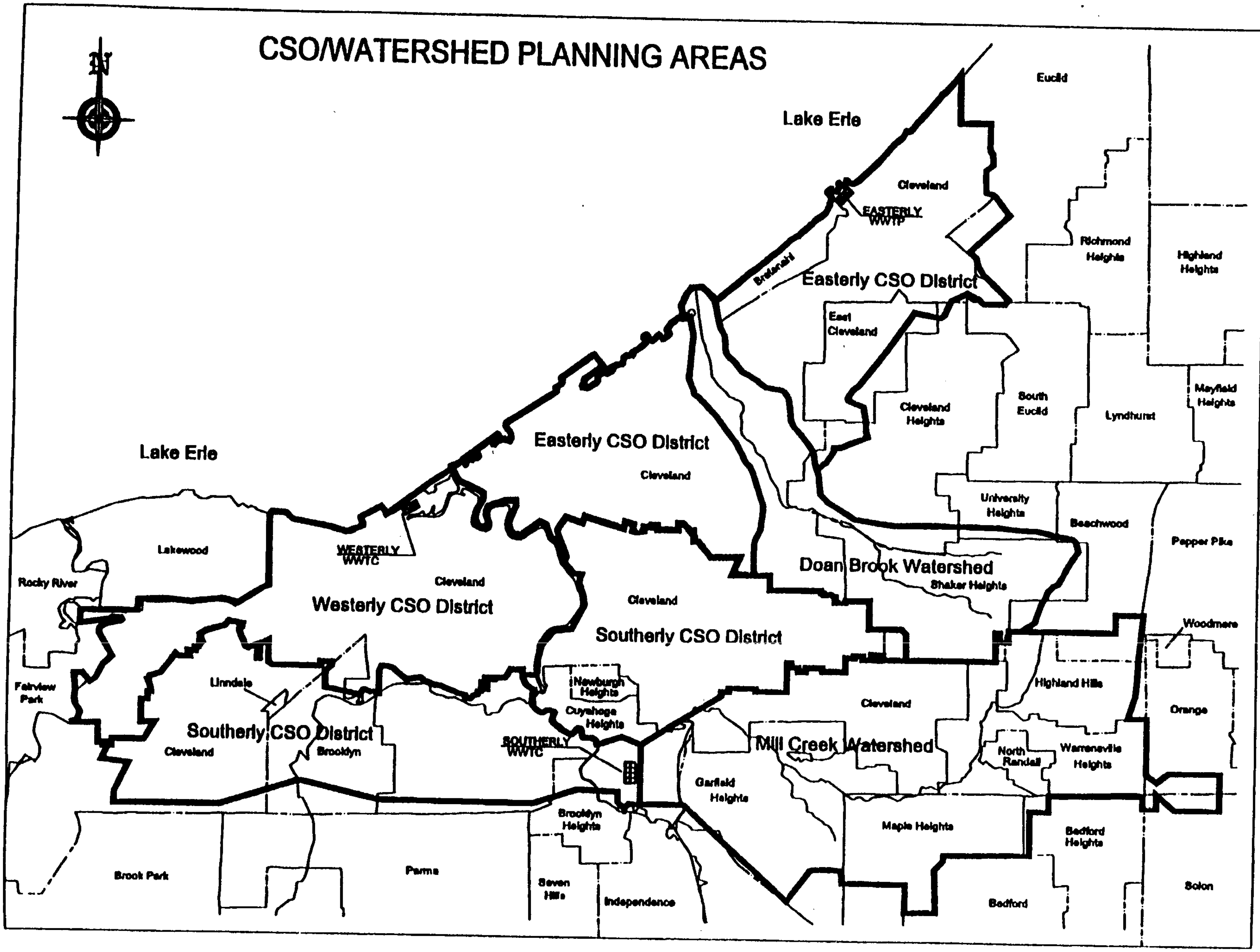
CSO/WATERSHED PLANNING AREAS
N
Lake Erie
Euclid
Cleveland
EASTERLY WWTP
Bratenahl
Richmond Heights
Highland Heights
Easterly CSO District
East Cleveland
Cleveland Heights
South Euclid
Lyndhurst
Mayfield Heights
Lake Erie
Easterly CSO District
Cleveland
University Heights
Beachwood
Pepper Pike
Lakewood
WESTERLY WWTC
Cleveland
Rocky River
Westerly CSO District
Cleveland
Doan Brook Watershed
Shaker Heights
Southerly CSO District
Woodmere
Fairview Park
Linndale
Newburgh Heights
Highland Hills
Cuyahoga Heights
Cleveland
Orange
Southerly CSO District
Cleveland
Brooklyn
SOUTHERLY WWTC
Mill Creek Watershed
North Randall
Warrensville Heights
Garfield Heights
Brooklyn Heights
Maple Heights
Bedford Heights
Brook Park
Parma
Seven Hills
Independence
Bedford
Solon

FIGURE 1

COMMON TRENCH SEPARATE SANITARY SEWERS

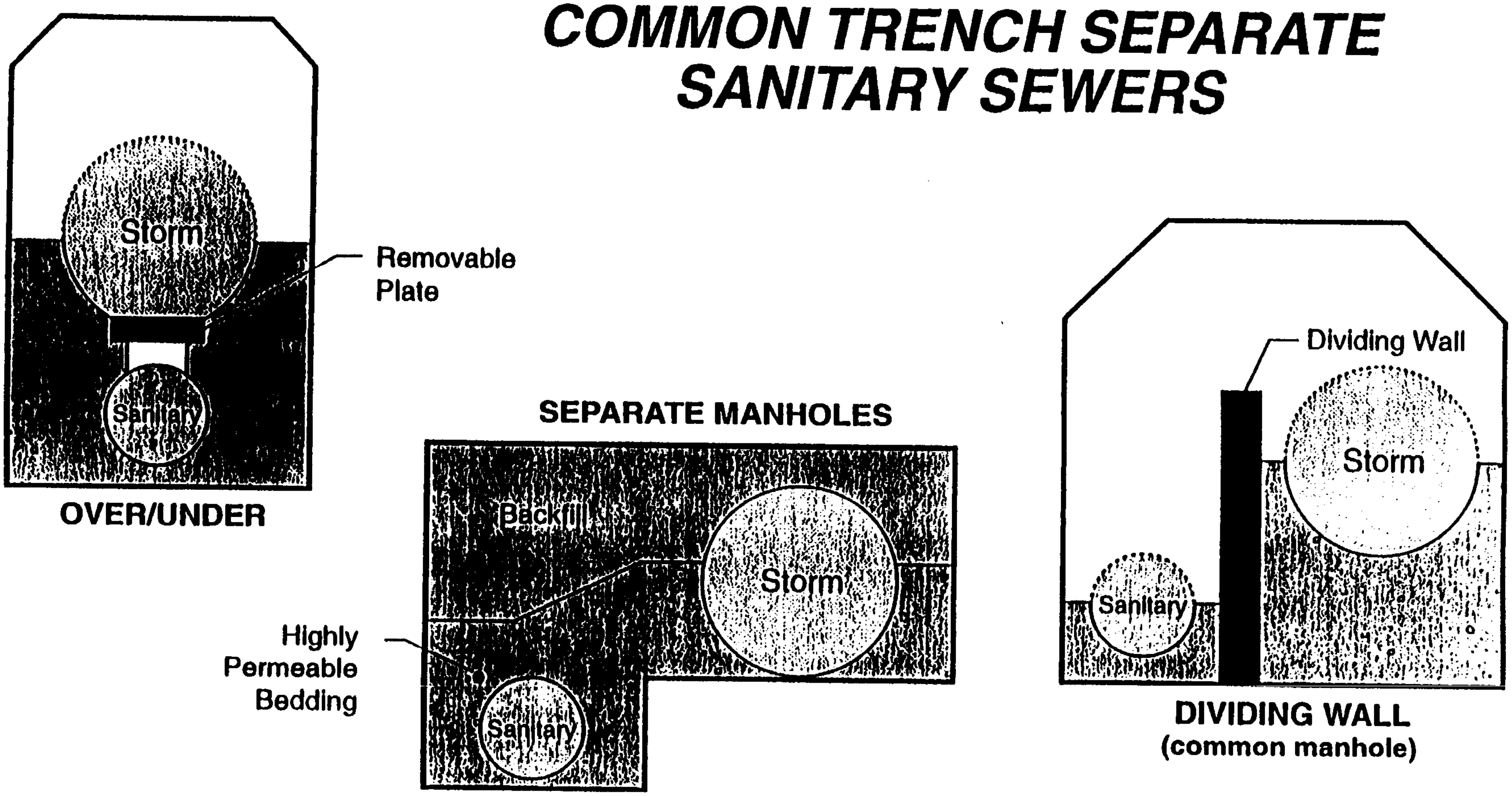

Figure 2

COMMUNITY DISCHARGE PERMIT PROGRAM

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ABSTRACT

The Community Discharge Permit Program was established as a result of grant conditions for the District's Heights-Hilltop (HHI) and Southwest (SWI) Interceptors. The Community Discharge Permit system is applied to communities serviced by separate sewers areas in the District service area. Two important aspects of the Community Discharge Permit Program are the Performance Objectives, which includes the control of separate sanitary sewer overflows (SSOs) and the establishment of peak flow limitations at designated design storms, and the Community Compliance Plan, which includes required Technical Program projects and reporting on community best management practices.

INTRODUCTION

The Northeast Ohio Regional Sewer District (District) received significant grants from the EPA for the construction of the Southwest Interceptor and Heights-Hilltop Interceptor. Conditions of the grant included the adoption of regulations to monitor flows entering the Interceptor sewers, essentially providing protection of the investment of grant funds into the District's interceptor system. In response to these grant conditions, the District developed Title III - Separate Sanitary Sewer Code of its ***Code of Regulations***. Title III provides a procedure by which the District and each member community served by District facilities can cooperate to control SSOs and peak flows from community sewer systems at the point of connection into sewers owned by the District or another community.

COMMUNITY DISCHARGE PERMIT PROGRAM ITEMS

In 1986, the Community Discharge Permit Program was established to implement Title III and issue Permits to communities serviced by separate sewers. Forty-five (45) communities have been issued Community Discharge Permits. The Community Discharge Permits consist of the following attachments:

- Attachment A - General Conditions
    - ⇒ No Improper Connections
    - ⇒ Identify SSOs
    - ⇒ No new SSOs
    - ⇒ Implement sewer maintenance program (Best Management Practices - BMP)
- Attachment B - Performance Objectives
    - ⇒ Control SSOs to the applicable design storm
    - ⇒ Establish Peak Flow Limitations at design storm
- Attachment C - Community Compliance Plan
    - ⇒ Annual Compliance Report Checklist
    - ⇒ Technical Program Projects
- Attachment D - Outline for Best Management Practice (BMP) Fact Sheet
- Attachment E - Approved Community Compliance Plan

TECHNICAL PROGRAM

Communities that have been issued Permits have been divided into two categories: Priority 1 communities and Priority 2 communities. Priority 1 communities are communities that face mandatory expenditures to construct relief sewer or rehabilitation projects need to achieve Performance Objectives as stated within Attachment B of the Community Discharge Permits. Communities are required to meet established Peak Flow Limitations at points of connection into sewers owned by the District or another community and control SSOs to specified design storms. However, previous sewer system evaluation survey (SSES) studies have found that many existing sewer systems lack the necessary capacity to meet the performance objectives. Therefore, the SSES recommended rehabilitation and relief sewer projects necessary for the communities to meet the established peak flow limitations.

The recommended projects are included in the community's Permit Technical Program. Fourteen communities have been identified as Priority 1 communities with required Technical Program projects. A summary of the completion status of the Technical Program Projects is included in Table 1.

Table 1 **Technical Program Project Statistics**

Total Number of Community Projects	91	
SWI Tributary Area Communities	35	
HHI Tributary Area Communities	56	
Total Number of Community Projects Complete	55	(60.5%)
SWI Tributary Area Communities	23	
HHI Tributary Area Communities	32	

SEPARATE SANITARY SEWER OVERFLOWS

The construction of many of the community technical program projects have resulted in the alleviation of many of the SSOs in the member community sewer system. The Technical Program projects include relief sewers which provide needed capacity to convey the wastewater flows, and rehabilitation projects to reduce infiltration and inflow (I/I) in the sewer system, thus freeing capacity to convey wastewater flows. The District has completed the construction of the SWI and is nearing the completion of the HHI, thus providing capacity for the local sewer system improvement projects. The District is also construction a series of intercommunity relief sewers, to assist in the conveyance of intercommunity flow (flow from 2 or more communities) to District interceptors.

As a result of the completion of several projects, both District and community, several SSOs have been alleviated. A summary of the operational status (alleviated or uncontrolled) status of the SSOs is included in Table 2.

Table 2 **Status of Sanitary Sewer Overflows**

Total Number of Sanitary Sewer Overflows in Permits	187
SWI Tributary Area Communities	74
HHI Tributary Area Communities	113
SSO's Alleviated	39% (73 out of 187)
SSO's Uncontrolled	61% (113 out of 187)
SSO's Alleviated in SWI Tributary Area Communities	51
SSO's Alleviated in HHI Tributary Area Communities	22

A breakdown by community of SSOs in the Community Discharge Permits and the number of required Technical Program projects is included in Table 3.

Table 3 **SSO and Technical Program Project Breakdown by Community**

Community	*SSOs in Permits*	*# Technical Program Projects*
Beachwood	2	7
Berea	19	3
Brook Park	17	19
Brooklyn	4	
Cleveland	2	2
Cleveland Heights	42	21
East Cleveland	4	2
Gates Mills	2	
Highland Heights	2	
Lyndhurst	3	8
Maple Heights	2	
Mayfield Heights	7	9
Mayfield Village	3	
Northfield	5	
Oakwood	1	
Parma	16	9
Parma Heights		2
Richmond Heights	4	
Sagamore Hills	1	
Seven Hills	1	
Shaker Heights	8	2
South Euclid	33	4
Strongsville	7	1
University Heights	2	2

BEST MANAGEMENT PRACTICES

The alleviation of SSOs in community sewer systems has been an ongoing, and sometimes difficult process. Communities perform Best Management Practices (typically sewer inspection and cleaning) to optimize the performance of the sewer system. Attachment D of the Community Discharge Permit contains a fact sheet outline for community Best Management Practices. The communities are required to identify their community BMP programs.

Table 4 contains a summary of information communities are required to provide regarding their Best Management Practices.

Table 4 **Best Management Practices Fact Sheet Outline**

	Section	Topic	Subtopic
A.	Cleaning	Sewers	Frequency Method Employed Additional Information
		Overflows	Frequency Additional Information
B.	Inspection	Sewers	Frequency Additional Information
		Manholes	Frequency Additional Information
C.	Emergency Contract and Repair Procedures		

The general conditions of the Community Compliance Plan require that each community submit an Annual Compliance Report to provide information on the operation and maintenance of the community's sewer system. An Annual Compliance Report Checklist is sent to the communities to assist in submitting the necessary sewer system information (see Table 5 for additional information).

Table 5 **Typical Questions in the Annual Compliance Report Checklist**

- Has the community met its Technical Program milestone dates for the reporting year?
- Has the community complied with their Best Management Practices for the reporting year?
- Has the community performed any sewer system studies, investigations or monitoring?
- Is the community aware of any new SSOs within the boundaries of the community?
- How much has the community spent on capital improvements to comply with the Permit?
- Have any extensions of service been completed in the last 12 months?
- Are any extensions of service anticipated in the next 12 months?
- Has the community updated is sanitary sewer map during the reporting year?

CONCLUSION

The Community Discharge Permit Program was established to regulate flows from member communities to the environment through SSOs and into facilities owned by the District or another community. Member communities have made significant expenditures to control I/I and alleviate SSOs. As a result, the Permit Program has increased community awareness on the need for BMP to meet the Performance Objectives stated in the Permit.

Current Water Quality Conditions in the Greater Cleveland Area

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Abstract

The quality of the waters of the Cuyahoga River and Lake Erie in the vicinity of Cleveland, Ohio have been substantially improved over the last two decades. The natural conditions of the river system, with its low seasonal flow and high suspended solids, has contributed to many of its problems. Efforts of the Northeast Ohio Regional Sewer District and other point source dischargers to the river have eliminated virtually all water quality standard violations. Several water quality problems remain. The Northeast Ohio Regional Sewer District will attempt to address the remaining issues in its future planning activities.

KEYWORDS

Cuyahoga River, Lake Erie, wastewater, treatment, water quality

GEOLOGY OF THE GREATER CLEVELAND AREA

The water quality conditions of the Greater Cleveland area may be better understood with some background information of its geology and history. Lake Erie was formed about 20,000 years ago during the last ice age, known as the Wisconsin Stage, when glaciers dug out the Great Lakes. As the glaciers receded, the ground-up rocks, boulders, pebbles, sand and clay; collectively known as glacial till, formed hills to the south of where Cleveland is now located. To the east, the area now known as the Heights are on the westemmost foothills of the Appalachian Mountains. The land to the west is a flat terrain scrapped by the glaciers and covered with a thick layer of clay laid down by glacial lakes as the glaciers receded. A deep river valley separated the Appalachian escarpment (to the east) from the flatland (to the west). This ancient, deep, preglacial valley, filled in with glacial debris, is the current alignment of the main stem of the Cuyahoga River.

The source of the Cuyahoga River is on the Appalachian escarpment. The headwaters of the Cuyahoga River have an elevation of 1,300 feet above sea level and the river has an average fall of about 4 feet per mile. As the river moves southward, from its source towards Akron, it falls at a rate of about 25 feet per mile. This 71 mile-long river drops off the escarpment at the Cuyahoga gorge in a series of waterfalls then turns northward cutting through the aforementioned glacial deposits and carving out the wide, deep Cuyahoga River valley. Borings done in conduction with sewer interceptor projects indicate that clay and silt layers can be as deep as 41 feet below the bed of the river. Sediment transport studies conducted by Heidelberg University state that the Cuyahoga River has the greatest concentrations (time weighted mean concentration) of suspended solids among the eight Lake Erie tributary rivers studied. With rain, the river transports large concentrations of mud and silt. During dry weather the river is remarkably clear, a tribute to the fact that during low flow periods, and about 80% of the river is from sewage treatment plants.

The river and its tributaries drain a small area as far as rivers with big reputations go. The river drains 813 mi^2 (1,300 $kilometers^2$), which includes over 100 cities and townships with two major urban areas; Akron and Cleveland, before its relatively small volume empties into Lake Erie. The average flow of the Cuyahoga River is 1,200 ft^3/sec (36 m^3/s), which is 17% of the flow of Toledo's Maumee River and 0.5% of the flow coming down the Detroit River. Because of this relative small flow and high sediment yield, it did not need much human intervention to cause major pollution problems. Early explorers noted that the river was naturally contaminated, emitting a noxious odor.

HISTORY OF THE CUYAHOGA RIVER

The Cuyahoga River was known to the founding fathers of our Country. Upon a recommendation from Benjamin Franklin in 1765, Thomas Jefferson authorized a fort to be built at the mouth of the Cuyahoga River. As this location was strategically located between the iron ore field of the West and coal mines in the East, the Greater Cleveland area became an early manufacturing center. Major pollution problems of the river can be traced back to the mid 1800's when the City of Cleveland had 20 oil refineries, including the largest refinery in the world. A brochure produced by the Standard Oil Company boasted that its Cleveland refinery used more water than the entire city of Cincinnati. Cleveland also had the world's largest iron-ore receiving port and numerous iron mills along the river. For over a century, the Cuyahoga River was a working river providing both transportation and waste disposal functions.

FIRES ON THE CUYAHOGA RIVER

The first report of a Cuyahoga River fire was in 1902. The river was so polluted with oil and debris that, in 1936, river debris caught fire by a welder's torch and burned for five days! The river burned again in 1952. Even so, the river was not perceived by the public to be polluted. Pollution had another meaning for people in times past. The oil-laden river and dirty smoke emitted by smokestacks were symbols of prosperity. The river was a working river and Lake Erie was thought to provide an infinite source of dilution of the oils and chemicals that were discharged to the river.

By the 1960s, however, Lake Erie and other Great Lakes were showing signs that they could no longer assimilate the massive amount of sanitary and industrial wastewater that was being discharged by the 45 million people living and working around the Great Lakes area. Lake Erie, being the smallest in volume of the Great Lakes, was eutrifying at an alarming rate. It was estimated that half of the bottom of Lake Erie had become anoxic, that is, devoid of oxygen, due to decaying organic material. In the summer of 1969, the Cuyahoga River again caught fire. It was reported in Time Magazine, shortly after this fire, "Some river! Chocolate-brown, oily, bubbling with subsurface gases, it oozes rather than flows." "Anyone who falls into the Cuyahoga does not drown," Cleveland citizens joke grimly, "he decays." The Federal Water Pollution Control Administration noted that the lower Cuyahoga has no visible life, not even lower forms such as leeches and sludge worms. Clearly, this time the fire was not perceived as a symbol of prosperity but a sign of disgrace. The burning of the Cuyahoga River became a national symbol of just how polluted we let our waters become. There was a tremendous ground swell of support and demand from the public to clean up our waterways. Although lasting only 28 minutes, this famous conflagration was one of the banners for the social movement that lead to the Federal Water Pollution Control Act Amendments of 1972.

PROBLEMS IN LAKE ERIE

Lake Erie had its share of problems too: Eutrophication/over enrichment of nutrients, ever increasing algae blooms, malodorous algae mats washing up on beaches and settling to the bottom to decay. This decay caused widespread anoxia in Lake sediments. This, along with over-fishing, was the cause of the extirpation of the prized blue pike. Lake Erie, in the 70's, became the butt of national jokes. There were comments about Lake Erie dying or Lake Erie was dead. Lake Erie never died in the conventional sense. The fact is that the opposite was true. The Lake was becoming too productive. The Lake passed rapidly from Oligotrophic to eutrophic. It changed from a clear lake into the early stages of a swamp, with ever-increasing algae blooms and loss of diversity, including the loss of prize game fish and anaerobic benthic conditions.

The Lake has rebounded. With phosphate reductions in detergents, phosphate control at sewage treatments and upgrades to secondary treatment, the Lake was declared to have passed back to oligotrophic conditions in 1984. Ironically, with the advent of the zebra mussels in the late 80's and early 90's, recently, it has been suggested that perhaps the Lake is too clean to support its excellent walleye and perch fishery.

IMPROVEMENTS IN WATER QUALITY

The improvement in the water quality of Lake Erie is one example of the substantial improvement to area waters. These improvements have been brought about by over a billion dollars of infrastructure improvements and industrial wastewater control by; the NEORSD, the City of Cleveland and area industries. The improvement was so dramatic that AMSA considered the improvements to the water quality of the Cuyahoga River as one the major "Clean Water Success Stories."

The Southerly Wastewater Treatment Plant, situated at about River Mile 10.3, contributes as much as 50% of the total flow in the river during the summertime low flow periods. Consequently, any major change in the character of the plant effluent will have a significant impact on the water quality of the river. Due to industrial waste control and major reconstruction of this treatment facility, substantial reductions in pollutant loading were realized. The following table highlights the reductions in pollutants discharged to the river over time.

Table 1. Southerly WWTP- Percent reductions in pollutant parameters

Parameter	Time period	Percent Reductions
Cadmium	1977 to present	98%
Zinc	1977 to present	95%
Total Metals	1977 to present	92%
Ammonia	1977 to present	97%

Table 2. Cuyahoga River- Water Quality Improvements

Parameter	Time period	Percent Reductions
Ammonia*	1986 to present	89%
Fecal Coliform*	1977 to present	96%
*downstream of Southerly		

There are other notable water quality improvements in the Cuyahoga River. Dissolved Oxygen violations were once very common in the main stem of the Cuyahoga River. There hasn't been a recorded violation since 1988. Metals, including copper, nickel, chrome and zinc, have been reduced by 89% since 1978. These improvements in regional water quality came about by water pollution control programs to reduce pollutants by better transport and treatment. Many of the programs to reduce CSO and SSO flow during wet weather are currently under design so that the impacts will not be seen for some years to come.

The water quality of the Greater Cleveland area has improved dramatically over the last 30 years, i.e., not to suggest that all of the problems have been dispatched. Several major problems still remain. Some of these problems, I suspect, are due to optimistic expectations as much as they are due to point or nonpoint discharges.

- The State of Ohio has chemical and biological standards for assessing compliance with water quality standards. It is a rare event to find a violation of chemical standards. The Ohio EPA and the NEORSD have found that the number of species of fish found in the Cuyahoga River has increased from a low of one or two species in 1984 to a cumulative total of 51 species in recent years. The main stem of the Cuyahoga River still does not meet the State's biological criteria because the Index of Biotic Integrity (IBI) scoring is still too low. That is to say; that the IBI indicates that the Cuyahoga River does not have sufficient populations of certain preferred types of fish, like darters, bass, etc. It may well be that the poor fishery has more to do with geological conditions, soil erosion and bedload movement. These are habitat issues. This is consistent with the State's 305b Report which declared that the major cause for impairment in Ohio is nonpoint source pollution and hydro-modification, not point source discharges.

- Although substantial reductions have been observed, the sediments of the shipping channel are still considered heavily polluted for a number of heavy metals and oxygen demanding parameters.

- The river conveys an enormous amount of tree trunks, root masses, branches, and other woody material from trees that were undermined in the forested area between Cleveland and Akron. This, along with a muddy appearance following a rain event, detracts significantly from the aesthetics of the river and detracts from boating and other recreational uses. Floating debris removal is currently under study by the NEORSD.

- The shipping channel will have several days in the summer time that the DO falls below the dissolved oxygen criterion. This again has much to do with the fact that the shipping channel is dredged to maintain a depth of 26 feet. This depth is too great for the low summer time flows to adequately maintain aeration through its entire depth.

- Most area streams fail to meet the State's biological criteria.

- Bacterial levels in many of the smaller urban streams are impacted with bacteria due to aging separate sewer infrastructure with its many cross connections, breaks, and leaks.

Our own planning studies are indicating that even with the full implementation of the CSO control program, the area waters will still fail to meet all of the water quality standards and solve the above-listed problems. A report issued by Ohio EPA, as part of the 305 planning process, indicates that by the year 2002 only 1.6% of the impacted waters of Ohio are so because of point sources. There is good reason to believe that nonpoint sources are the continuing cause of water quality impairments. These problems transcend the traditional "transport and treat" role of the Northeast Ohio Regional Sewer District. In order to successfully address these remaining issues, the District may expand its traditional function into new areas where it can exert some control over nonpoint issues; restoring urban stream habitat, stormwater and drainage control, and intercommunity flood control.

REFERENCES

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CONSIDERATIONS FOR THE FUTURE

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ABSTRACT

This presentation provides wrap up for the nine preceding presentations regarding various aspects of the Northeast Ohio Regional Sewer District wet weather programs and comment on considerations for the future.

KEYWORDS

sewer, storm, sanitary, combined, overflow

EQUITABLE CHARGES FOR WET WEATHER FLOW

The Northeast Ohio Regional Sewer District rate structure has historically been based on metered water consumption. Over the years, water consumption has decreased. On the other hand, sewer systems have deteriorated and wet weather programs have increased wastewater flows. Water consumption decreased from 55 to 46 billion gallons per year since 1980 (16 percent) while treated wastewater increased from 92 to 122 (33 percent).

COMBINED SEWER OVERFLOW CONTROL

The District is developing Combined Sewer System Long-Term Control Plans on a segmented basis. The current National Pollutant Discharge Elimination System Permit requires all plans to be complete by March, 2002. The Mill Creek plan is complete. The Westerly, Easterly, and Doan Brook plans are currently underway. The Southerly and Big Creek plans will begin next year.

SEPARATE SEWER OVERFLOWS

Many District member communities have separate sewer overflows. Many have been alleviated through the intercommunity relief sewer program. However, many more need to be addressed.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY PROPOSED STORM WATER PHASE II RULE

Since no District member community meets the 100,000 population criteria for the Storm Water Phase I Rule, no permits have been issued or applied for in the Cleveland metropolitan area. However, many communities will be impacted by the Phase II Rule.

REGIONAL PLAN FOR SEWERAGE AND DRAINAGE

The court order that created the District mandated that "The District shall develop a detailed integrated capital improvement plan for regional management of wastewater collection and storm drainage to identify a capital improvement program for the solution of all intercommunity drainage problems (both storm and sanitary) in the District". Although the District has made substantial progress in the "wastewater collection" area, the "storm drainage" area is still "unfinished business". Work on Phase I of the comprehensive Regional Plan for Sewerage and Drainage began early this year.

INNOVATIVE MULTI-CHAMBERED STORMWATER CONTROL DEVICE FOR CRITICAL SOURCE AREAS

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ABSTRACT

This research project is part of a multi-year investigation funded by the U.S. EPA to characterize and treat toxic stormwater contaminants. The first project phase investigated typical toxicant concentrations in stormwater, the origins of these toxicants, and storm and land-use factors that influenced these toxicant concentrations. Nine percent of the eighty-seven stormwater source area samples analyzed were considered extremely toxic. Thirty-two percent of the samples exhibited moderate toxicity, while fifty-nine percent of the samples had no evidence of toxicity. All metallic toxicants analyzed were commonly found in all samples analyzed. Only a small fraction of the organic toxicants analyzed were frequently detected, with 1,3-dichlorobenzene and fluoranthene the most commonly detected organics (present in 23 percent of the samples). Vehicle service and parking area runoff samples had many of the highest observed concentrations of organic toxicants.

The second project phase investigated the control of stormwater toxicants using a variety of conventional bench-scale treatment processes. The most beneficial treatment tests included settling for at least 24 hours (up to 90% reductions), screening and filtering through at least 40 µm screens (up to 70% reductions), and aeration and/or photo-degradation for at least 24 hours (up to 80% reductions). Because many samples exhibited uneven toxicity reductions for the different treatment tests, a treatment train, called the MCTT (multi-chambered treatment train), was designed and constructed for pilot-scale and full-scale testing during the third project phase.

The third project phase included testing of a prototype MCTT). This device, through pilot and initial full-scale testing has been shown to remove more than 90% of many of the stormwater toxicants, in both particulate and dissolved forms. The MCTT is most suitable for use at relatively small and isolated paved critical source areas (gas stations, oil change stores, salvage yards, maintenance yards, etc.) that are about 0.1 to 1.0 ha (0.25 to 2.5 acres) in area. The MCTT is an underground device that has three main chambers: an initial grit chamber with volatile organic removal; a settling chamber with sorbents for the removal of fine sediments and floating hydrocarbons; and a sand/peat filter for the removal of filterable toxicants. A typical MCTT requires between 0.5 and 1.5 percent of the paved drainage area, about 1/3 of the area required for a well-designed wet detention pond.

The pilot-scale MCTT, constructed in Birmingham, AL, was tested over a six-month monitoring period during a variety of rainfall events. Two additional full-scale MCTT units were also constructed and were monitored as part of Wisconsin's 319 grant from the U.S. EPA. During monitoring of 13 storms at a parking facility, the pilot-scale MCTT was found to have the following overall removal rates: 96% for total toxicity, 83% for suspended solids, 60% for COD, 40% for turbidity, 90-100% for heavy metals, 90-100% for the detected semi-volatile organics. The peat filter caused a color increase in the effluent and an overall drop in pH of about one-half unit. Ammonia nitrogen was increased and nitrate-nitrogen had less than 20% removals. The MCTT operated as intended: very effective removal rates for both filtered and particulate stormwater toxicants and suspended solids, but at the expense of increased color, lowered pH, and depressed COD and nitrate removal rates. The full-scale test results substantiate the excellent removals found during the pilot-scale tests, while showing better control of COD and nutrients and less detrimental effects on pH and color.

R0024905

KEYWORDS

Urban runoff treatment, settling chamber, sand/peat filter, wet weather flows

INTRODUCTION

Runoff from paved parking and storage areas, and especially gas station areas, has been observed to be contaminated with concentrations of many critical pollutants. These paved areas are usually found to contribute most of the toxicant pollutant loadings to stormwater outfalls. Polycyclic aromatic hydrocarbons (PAHs), the most commonly detected toxic organic compounds found in urban runoff, along with heavy metals are mostly associated with automobile use, especially during starting vehicles.

Numerous manufacturers have developed small prefabricated separators to remove oils and solids from runoff. These separators are rarely specifically designed and sized for stormwater discharges, but usually consist of modified grease and oil separators. The solids are intended to settle within these separators, either by free fall or by counter-current or cross-current lamellar separation. Many of these separators have been sold and installed in France, especially along highways (Rupperd 1993). Despite the number of installations, few studies have been carried out in order to assess their efficiency (Aires and Tabuchi 1995). Available results from Fourage (1992), Rupperd (1993) and Legrand, *et al.* (1994) for stormwater treatment show that:

- These devices are usually greatly undersized. They should work reasonable well at flow rates between 20 and 30% of their design hydraulic capacity. For higher flow rates, the flow is very turbulent (Reynolds numbers > 6000) and the removal efficiency is very poor.
- These devices need to be cleaned very frequently. If they are not cleaned, the deposits are scoured during storm events, with negative efficiencies. Currently, the cleaning frequencies are very insufficient and the stormwater pollutant control efficiencies are very limited.
- There are relatively low levels of free-floating oils in most stormwater runoff.

Prefabricated separators could be used for stormwater treatment if the following conditions are respected:

- realistic design hydraulic capacity in terms of maximum flow rates, flow distribution and flow regime;
- realistic solids removal efficiency: the finest and polluted solids will usually not be trapped with a high efficiency because of too high hydraulic velocities;
- frequent cleaning and/or an automatic extraction to assure good overall efficiency;
- specific conception for stormwater that takes into account the solids characteristics, the rapid flow variations, and the maintenance requirements.

METHODOLOGY

The Multi-Chambered Treatment Train (MCTT) was developed to specifically address many of the above concerns. It was developed and tested with specific stormwater conditions in mind, plus it has been tested at several sizes for the removal of stormwater pollutants of concern. Figure 1 shows a general cross-sectional view of a MCTT. It includes a special catchbasin followed by a two chambered tank that is intended to reduce a broad range of toxicants (volatile, particulate, and dissolved). The runoff enters the catchbasin chamber by passing over a flash aerator (small column packing balls with counter-current air flow) to remove highly volatile components. This catchbasin also serves as a grit chamber to remove the largest (fastest settling) particles. The second chamber serves as an enhanced settling chamber to remove smaller particles and has inclined tube or plate settlers to enhance sedimentation. This chamber also contains fine bubble diffusers and sorbent pads to further enhance the removal of floatable hydrocarbons and additional volatile compounds. The water is then pumped to the final chamber at a slow rate to maximize pollutant reductions. The final chamber contains a mixed media (sand and peat) slow filter/ion exchange device, with a filter fabric top layer. The MCTT is typically sized to totally contain all of the runoff from a 6 to 20 mm (0.25 to 0.8 in) rain, depending on interevent time, typical rain size, and rain intensity.

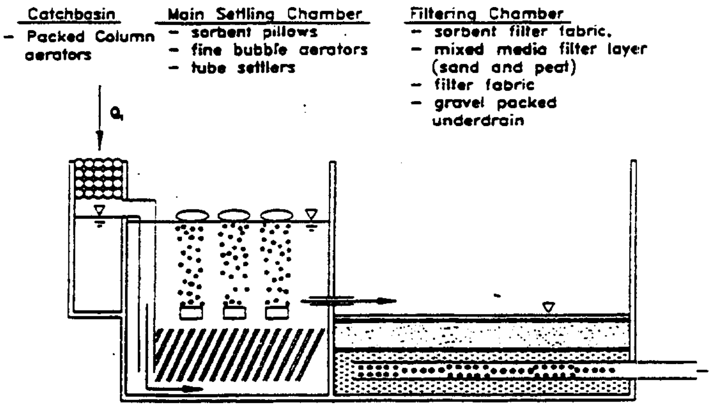

Figure 1. **General Schematic of the Multi-Chambered Treatment Train (MCTT)**

A pilot-scale MCTT was constructed and tested in Birmingham, Alabama, at parking and vehicle service area on the campus of the University of Alabama at Birmingham. The catchbasin/grit chamber is a 25-cm vertical PVC pipe containing about 6 L of 3-cm diameter packing column spheres. The main settling chamber is about 1.3 m^2 in area and 1 m deep which with a 72-hour settling time was expected to result in a median toxicity reduction of about 90%. The filter chamber is about 1.5 m^2 in area and contains 0.5 m of sand and peat directly on 0.15 m of sand over a fine plastic screen and coarse gravel that covers the underdrain. A Gunderboom™ filter fabric also covers the top of the filter media to distribute the water over the filter surface by reducing the water infiltration rate through the filter and to provide additional pollutant capture. During a storm event, runoff from the parking lot is pumped into the catchbasin/grit chamber automatically. During filling, an air pump supplies air to aeration stones located in the main settling chamber. When the settling chamber is full, all pumps and samplers cease. After a quiescent settling period of up to 72 hours, water is pumped through the filter media and discharged. Samples were collected before and after each chamber of the device and were partitioned into dissolved and particulate components before being analyzed for a wide range of toxicants, as listed on Table 1.

RESULTS

Observed Performance of the Pilot-Scale MCTT

Table 2 summarizes some of the significant percentage changes in concentrations of the constituents as they passed through each chamber (settling chamber, filter, and overall) of the MCTT. No data is shown for the catchbasin/grit chamber because of the lack of significant concentration changes observed. Figures 2 and 3 are example plots showing the concentrations of suspended solids and unfiltered zinc as the stormwater passed through the MCTT. The four data locations on these plots correspond to the four sampling locations on the MCTT. The sample location labeled "inlet" is the overall inlet to the MCTT (and the inlet to the catchbasin/grit chamber). The location labeled "catch basin" is the effluent from the catchbasin (and inlet to the main settling chamber). Similarly, the location labeled "settling chamber" is the outlet from the settling chamber (and the inlet to the sand/peat chamber). Finally, the location labeled "peat-sand" is the outlet from the sand/peat chamber (and the outlet from the MCTT). The slopes of the lines indicate the relative removal rates (mg/L reduction) for each individual major unit process in the MCTT. If the lines are all parallel between two sampling locations, then the removal rates are similar. If a line has a positive slope, then a concentration increase occurred. If the lines have close to zero slope, then little removal has occurred (as for the catchbasin/grit chamber for most constituents and samples).

The suspended solids trends (Figure 2) show the significant reductions in suspended solids concentrations through the main settling chamber, with no removal occurring in catchbasin/grit and sand/peat chambers. However, the first storm had a significant increase in suspended solids

R0024907

Table 1. **Compounds Analyzed during MCTT Pilot-Scale Testing**

Compound Category	Compounds	Testing Methodology (Detection Limits)
Semi-Volatile Organics (BNA Extractable)	Polycyclic Aromatic Hydrocarbons Phthalate Esters Phenols	GC/MSD – particulate and dissolved fractions (1 to 10 μg/L MDL)
Pesticides	Pesticides	GC/ECD – particulate and dissolved fractions (0.01 to 0.1 μg/L MDL)
Heavy Metals	Cadmium Copper Lead Zinc	GFAA – particulate and dissolved fractions (1 to 5 μg/L MDL)
Toxicity	Toxicity Screening Test	Microtox™ - particulate and dissolved fractions
Nutrients	Nitrite + Nitrate Ammonia Phosphate	Ion Chromatography – dissolved fraction (1 mg/L MDL)
Major Ions	Cations (Ca, Mg, K, Na, Li) Anions (Cl, SO_4, F)	Ion Chromatography – dissolved fraction (1 mg/L MDL)
Conventional Pollutants	Chemical Oxygen Demand Color Specific Conductance Hardness Alkalinity pH Turbidity Solids (total, dissolved, suspended, volatile)	
Particle Size	Particle Size Distribution (1 – 128 μm)	Coulter Multisizer IIe

Table 2. **Median Observed Percentage Changes in Constituent Concentrations**

Constituent	Main Settling Chamber	Sand/Peat Chamber	Overall Device
Common Constituents			
Total solids	31%	2.6%	32%
Suspended solids	91	-44	83
Turbidity	50	-150	40
pH	-0.3	6.7	7.9
COD	56	-24	60
Nutrients			
Nitrate	27	-5	14
Ammonia	-155	-7	-400
Toxicants			
Microtox™ (unfiltered)	18	70	96
Microtox™ (filtered)	64	43	98
Lead	89	38	100
Zinc	39	62	91
n-Nitro-di-n-propylamine	82	100	100
Hexachlorobutadiene	72	83	34
Pyrene	100	n/a	100
Bis (2-ethylhexyl) phthalate	99	-190	99

concentration as it passed through the peat due to flushing of fines from the incompletely washed media. This contributed to the negative removals of the filter chamber. For the other monitored storms, removal occurred (although the percent reduction was small). The relative toxicity changes (as measured using the Microtox™ unit) (not shown) indicate significant reductions in toxicity, especially for the moderate and highly toxic samples. No effluent samples were considered toxic (all effluent samples were "non toxic", or causing less than a 20% light reduction after 25 minutes of exposure using the Azur Microtox™ screening toxicity test). Figure 3, for zinc removal, shows significant and large reductions in concentrations, mostly through the main settling chamber (corresponding to the large fraction of stormwater toxicants found in the particulate sample fraction). Zinc also had further important decreases in concentrations in the peat/sand chamber, where removal of the remaining dissolved zinc in the stormwater occurred.

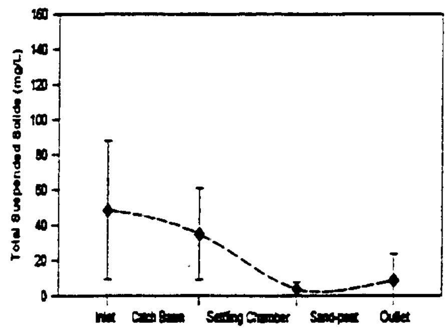

Figure 2. **MCTT Performance for Suspended Solids**

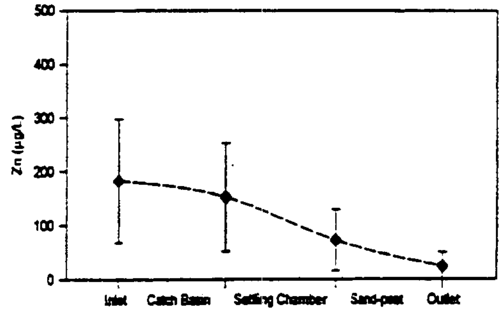

Figure 3. **MCTT Performance for Unfiltered Zinc**

Preliminary Full-Scale MCTT Test Results

Preliminary results from the full-scale tests of the MCTT in Wisconsin (Corsi, Blake, and Bannerman, personal communication) were encouraging and corroborate the high levels of treatment observed during the Birmingham pilot-scale tests. Table 3 shows the treatment levels that have been observed during seven tests in Minocqua (during one year of operation) and 15 tests in Milwaukee (also during one year of operation), compared to the pilot-scale Birmingham test results (13 events). These data indicate high reductions for SS (83 to 98%), COD (60 to 86%), turbidity (40 to 94%), phosphorus (80 to 88%), lead (93 to 96%), zinc (90 to 91%), and for many organic toxicants (generally 65 to 100%). The reductions of dissolved heavy metals (filtered through 0.45 µm filters) were also all greater than 65% during the full-scale tests. None of the organic toxicants were ever observed in effluent water from either full-scale MCTT, even considering the excellent detection limits available at the Wisconsin State Dept. of Hygiene Laboratories that conducted the analyses. The influent organic toxicant concentrations were all less than 5 µg/L and were only found in the unfiltered sample fractions. The Wisconsin MCTT effluent concentrations were also very low for all of the other constituents monitored: <10 mg/L for SS, <0.1 mg/L for phosphorus, <5 µg/L for cadmium and lead, and <20 µg/L for copper and zinc. The pH changes in the Milwaukee MCTT were much less than observed during the Birmingham pilot-scale tests, possibly because of added activated carbon in the final chamber in Milwaukee. Color was also much better controlled in the full-scale Milwaukee MCTT.

DISCUSSION

The Milwaukee installation is at a public works garage and serves about 0.1 ha (0.25 acre) of pavement. This MCTT was designed to withstand very heavy vehicles driving over the unit. The estimated cost was $54,000 (including a $16,000 engineering cost), but the actual cost was $72,000. The high cost was likely due to uncertainties associated with construction of an unknown device by the contractors and because it was a retrofit installation. It therefore had to fit within very tight site layout constraints. As an example, installation problems occurred due to sanitary sewerage not being accurately located as mapped. The Minocqua site was a 1 ha (2.5 acre) newly paved parking area serving a state park and commercial area. It was located in a grassed area and was also a retrofit installation, designed to fit within an existing storm drainage system. The installed cost of this MCTT was about $95,000.

It is anticipated that MCTT costs could be substantially reduced if designed to better integrate with a new drainage system and not installed as a retrofitted stormwater control practice. Plastic tank manufactures have also expressed an interest in preparing pre-fabricated MCTT units that could be sized in a few standard sizes for small critical source areas. It is expected that these pre-fabricated units would be much less expensive and easier to install than the custom-built units tested to date.

Table 3. **Preliminary Performance Information for Full-Scale MCTT Tests, Compared to Birmingham Pilot-Scale MCTT Results (median reductions and median effluent quality)**

	Milwaukee MCTT (15 events)	**Minocqua MCTT (7 events)**	**Birmingham MCTT (13 events)**
suspended solids	98 (<5 mg/L)	85 (10 mg/L)	83 (5.5 mg/L)
volatile suspended solids	94 (<5 mg/L)	na[a]	66 (6 mg/L)
COD	86 (13 mg/L)	na	60 (17 mg/L)
turbidity	94 (3 NTU)	na	40 (4.4 NTU)
pH	-7 (7.9 pH)	na	8 (6.4 pH)
ammonia	47 (0.06 mg/L)	na	-210 (0.31 mg/L)
nitrates	33 (0.3 mg/L)	na	24 (1.5 mg/L)
Phosphorus (total)	88 (0.02 mg/L)	80 (<0.1 mg/L)	nd[b]
Phosphorus (filtered)	78 (0.002 mg/L)	na	nd
Microtox® toxicity (total)	na	na	100 (0%)
Microtox® toxicity (filtered)	na	na	87 (3%)
Cadmium (total)	91 (0.1 μg/L)	na	18 (0.6 μg/L)
Cadmium (filtered)	66 (0.05 μg/L)	na	16 (0.5 μg/L)
Copper (total)	90 (3 μg/L)	65 (15 μg/L)	15 (15 μg/L)
Copper (filtered)	73 (1.4 μg/L)	na	17 (21 μg/L)
Lead (total)	96 (1.8 μg/L)	nd (<3 μg/L)	93 (<2 μg/L)
Lead (filtered)	78 (<0.4 μg/L)	na	42 (<2 μg/L)
Zinc (total)	91 (<20 μg/L)	90 (15 μg/L)	91 (18 μg/L)
Zinc (filtered)	68 (<8 μg/L)	Na	54 (6 μg/L)
benzo(a)anthracene	>45 (<0.05 μg/L)	>65 (<0.2 μg/L)	nd
benzo(b)fluoranthene	>95 (<0.1 μg/L)	>75 (<0.1 μg/L)	nd
dibenzo(a,h)anthracene	89 (<0.02 μg/L)	>90 (<0.1 μg/L)	nd
fluoranthene	98 (<0.1 μg/L)	>90 (<0.1 μg/L)	100 (<0.6 μg/L)
indeno(1,2,3-cd)pyrene	>90 (<0.1 μg/L)	>95 (<0.1 μg/L)	nd
phenanthrene	99 (<0.05 μg/L)	>65 (<0.2 μg/L)	nd
pentachlorophenol	na	na	100 (<1 μg/L)
phenol	na	Na	99 (<0.4 μg/L)
pyrene	98 (<0.05 μg/L)	>75 (<0.2 μg/L)	100 (<0.5 μg/L)

na[a]: not analyzed
nd[b]: not detected in most of the samples

Design of the MCTT

__Catchbasin__. Catchbasins have been found to be effective in removing pollutants associated with coarser runoff solids. Moderate reductions in total and suspended solids (up to about 45%, depending on the inflow water rate) have been indicated by prior studies (Lager and Smith 1976, Pitt and Bissonnette 1985). While few pollutants are associated with these coarser solids, their removal decreases maintenance problems of the other chambers. The size of the MCTT catchbasin sump is controlled by three factors: the runoff flow rate, the suspended solids (SS) concentration in the runoff, and the desired frequency at which the catchbasin will be cleaned so as not to sacrifice efficiency.

Main Settling Chamber. The main settling chamber mimics completely mixed settling column bench-scale tests and uses a treatment ratio of depth to time for removal estimates. In addition to plate or tube settlers, the main settling chamber also contains floating sorbent "pillows" to trap floating grease and oil and a fine bubble diffuser. The settling time in the main settling chamber typically ranges from 1 to 3 days.

Peat/Sand Ion Exchange Chamber. Based on literature descriptions of stormwater filtration, especially by the City of Austin (1988), Galli (1990) and Shaver (undated and 1991), earlier UAB bench-scale treatability tests (Pitt, *et al.* 1995), and the preliminary UAB filter media column tests (Clark, *et al.* 1995), it was determined that a mixed media sand and peat "filter" should be used as a polishing unit after the main settling chamber. This unit provides additional toxicant reductions, especially for filtered forms of the organics and metals. The surface hydraulic loading rate of this filter/ion exchange chamber should be between 1.5 and 6 m per day (5 and 20 ft per day). The 50%/50% mixture of the sand and peat should have a depth of 0.5 m (18 in), resting on 0.15 m of sand. The sand used in the testing had the following size: 71% finer than #30 sieve (0.6 mm), 65% finer than #40 sieve (0.425 mm), and 0.5% finer than #50 sieve (0.18 mm). The effective size (D_{10}) of the sand was 0.31 mm and the uniformity coefficient (D_{60}/D_{10}) was 1.45. A filter fabric was used to separate these layers from the gravel and perforated pipe underdrain. In order to facilitate surface spreading of water on top of the media and to prevent channelization, another filter fabric (Gunderboom™) was placed on top of the media.

Example Design

The design of the MCTT is very site specific, since it is highly dependent on local rains (rain depths, rain intensities, and interevent times). A computer model was therefore developed to determine the amount of annual rainfall treated, the toxicity reduction rate for each individual storm, and the overall toxicity reduction associated with a long series of rains for different locations in the U.S. Table 4 gives the simulation results for the sizing of the main settling chamber for 21 cities (rain depths range from 180 mm (7.1 in) (Phoenix) to 1500 mm (60 in) (New Orleans) per year).

Table 4. **MCTT Settling Chamber Sizes (48 hr hold times, except as noted; 1.5 m settling depths)**

City	Annual Rain Depth (mm)	Runoff Capacity (mm) for 70% Toxicant Control	Runoff Capacity (in) for 90% Toxicant Control
Phoenix, AZ	180	6.35 (24 hours)	8.89
Reno, NV	191	5.08 (18 hours)	5.08
Bozeman, MT	325	6.35	10.2
Los Angeles, CA	378	7.62	11.4
Rapid City, SD	414	5.08 (18 hours)	5.59
Minneapolis, MN	671	8.13	2.70
Dallas, TX	749	2.70	24.4
Milwaukee, WI	785	9.14	16.5
Austin, TX	800	5.59 (18 hours)	8.13
St. Louis, MO	861	7.62	12.5
Buffalo, NY	953	8.89	2.70
Seattle, WA	986	6.35	10.2
Newark, NJ	1074	12.2	24.4
Portland, ME	1105	10.7	18.3
Atlanta, GA	1234	14.0	24.1
Birmingham, AL	1384	9.40	13.5
Miami, FL	1463	10.2	18.5
New Orleans, LA	1516	20.3	23.4

The overall range in MCTT size varies by more than three times for the same level of treatment for the different cities. The required size of the main settling chamber generally increases as the annual rain depth increases. However, the interevent period and the rain depth for individual rains determine the specific runoff treatment volume requirement. As an example, Seattle requires a much smaller MCTT than other cities having similar annual total rains because of the small rain depths for each rain. Rapid City requires a smaller MCTT, compared to Los Angeles, because Los Angeles has much larger rains when it does rain. Similarly, Dallas requires an unusually large MCTT because of its high rain intensities and large individual rains, compared to upper Midwest cities that have similar annual rain depths.

In all cases, the most effective holding time is 2 days for 90% toxicant control (for the 1.5 m, 5 ft, settling chamber depth). In most cases, a toxicity removal goal of about 70% in the main settling chamber is probably the most cost effective choice, considering the additional treatment that will be provided in the sand/peat chamber. Figure 4 shows the runoff volume requirements for an MCTT having a 0.6, 1.5, 2.1, or 2.7 m (2, 5, 7, or 9 foot) settling depths in the main settling chamber for Milwaukee, WI. This example shows that the required runoff depth storage capacity increases as the depth of the main settling chamber increases. As an example, for 90% toxicant control at Milwaukee, the storage requirement for a 1.5 m (5 ft) settling depth was shown to be 16.5 mm (0.65 in) on Table 2. Figure 4 indicates that the required storage volume for a 0.6 m (2 ft) settling chamber would only be 14 mm (0.55 in) of runoff, while it would increase to 19 mm (0.75 in) of runoff for a 2.1 m (7 ft) settling depth and to 23 mm (0.9 in) for a 2.7 m (9 ft) settling depth. The greater depths require more time for the stormwater particulates to settle and be trapped in the chamber, while the shallower tanks require a greater surface area. The best tank design for a specific location is based on site specific conditions, especially the presence of subsurface utilities or groundwater and hydraulic grade line requirements. A large surface tank is usually much more expensive, even though the required volume is less, especially if heavy traffic will be traveling over the tank.

A combination of a 48 hour holding time and 11 mm (0.45 in) runoff storage volume would satisfy a 75% treatment goal for Milwaukee conditions, as shown on Figure 3. This 11-mm runoff volume corresponds to a rain depth of about 13 mm (0.51 in) for pavement (Pitt 1987). The 11-mm runoff storage volume corresponds to a live chamber volume of 22 m^3 (770 ft^3) and a surface area of 10 m^2 (110 ft^2) for a 0.2 ha (0.5 acre) paved drainage area. The surface area of the MCTT would therefore be about 0.5 percent of the drainage area. This device would capture and treat about 80% of the annual runoff at a 95% toxicity reduction level, resulting in an annual toxicity reduction of about 75% (0.8 X 0.95). The size of the main settling chamber would need to be greater than this because about 0.7 m (two feet) of "dead" storage must be added to provided for standing water below the outlet orifice (or pump) which would keep the inclined tubes submerged. About a 0.2 m (6 inch) height is also needed below the inclined tubes for the flow distribution system and for long-term storage of fine material that will accumulate.

Additional treatment beyond the 75% level would result in the filter/ion exchange chamber. The pumped effluent from the main settling chamber would be directed towards a mixed peat/sand filter/ion exchange chamber, which must provide a surface hydraulic loading rate of between 1.5 and 6 m per day (5 and 20 ft per day), and have a depth of at least 0.5 m (18 in). In addition to the pumped effluent, any excess runoff after the main settling chamber is full would also be directed towards the filter.

Each of the treatment chambers need to be vented, mosquito proofed, and be easily accessible for maintenance. The device needs to be inspected, the initial catchbasin should be cleaned, and the sorbent pillows should be exchanged, at least every six months. It is expected that the ion exchange media should last from 3 to 5 years before requiring replacement (as determined during our filtration experiments).

CONCLUSIONS

The development and testing of the MCTT showed that the treatment unit provided substantial reductions in stormwater toxicants (both in particulate and filtered phases), and suspended solids. Increases in color and a slight decrease in pH also occurred during the filtration step at the pilot-scale unit. The main settling chamber resulted in substantial reductions in total and dissolved toxicity, lead, zinc, certain organic toxicants, suspended solids, COD, turbidity, and color. The filter/ion exchange unit is also responsible for additional filterable toxicant reductions. However, the catchbasin/grit chamber did not indicate any significant improvements in water quality, although it is an important element in reducing maintenance problems by trapping bulk material. The use of the MCTT is seen to be capable of reducing a broad range of stormwater pollutants that have been shown to cause substantial receiving water problems (Pitt 1995).

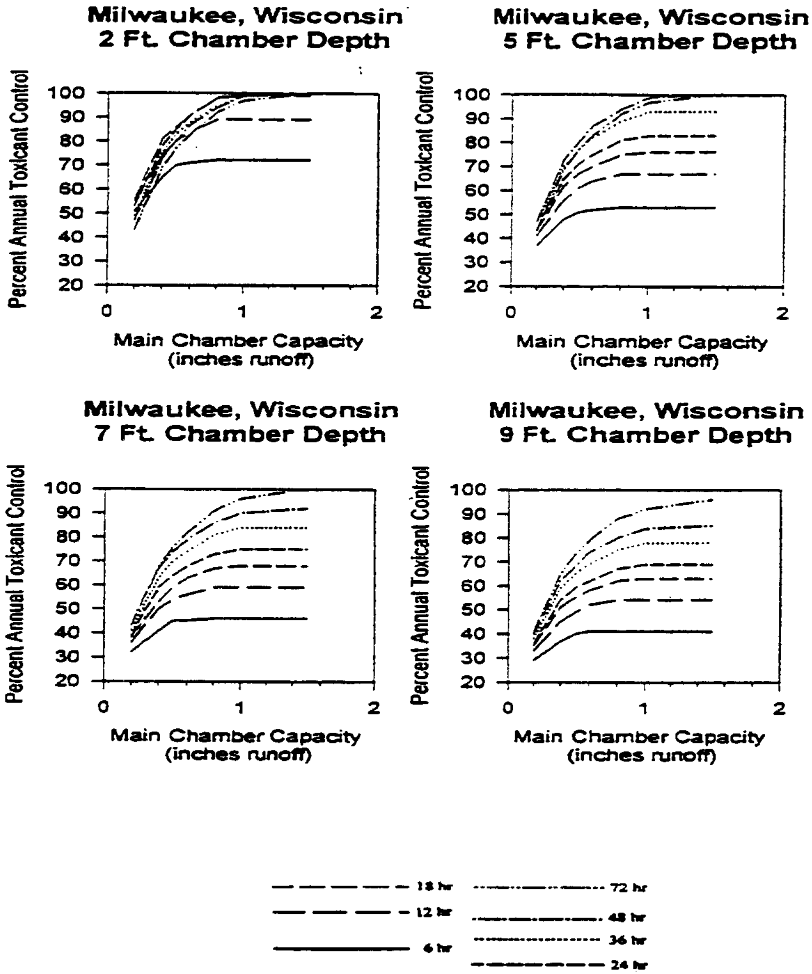

Figure 4. **MCTT Main Settling Chamber Required Capacities – Milwaukee, WI**

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HIGH-RATE DISINFECTION TECHNOLOGIES FOR WET-WEATHER FLOW (WWF)

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ABSTRACT

This paper presents the applicability of four high-rate disinfection technologies for treating combined-sewer overflow (CSO) and sanitary-sewer overflow (SSO). The four technologies are treatment with: ozone (O_3), chlorine dioxide (ClO_2), ultraviolet light irradiation (UV), and high-voltage electron beam irradiation (E-Beam). These high-rate technologies are compared to each other and to conventional chlorination/dechlorination. Utility of increased mixing in concert with any disinfection technology is also discussed.

Disinfection of CSO and SSO is generally practiced to control the discharge of pathogens and indicator microorganisms into receiving waters. Because these overflows are wet weather events, the disinfectant used at a facility for treatment of CSO or SSO should be adaptable to intermittent use. Other considerations include effectiveness, oxidation/disinfection rate, and safety. Since commonly used disinfection by chlorination forms toxic residual byproducts, the newer disinfectants such as ClO_2, O_3, UV, and E-Beam have a far lesser potential to generate toxic byproducts. Since CSO and SSO flow rates and volumes are significantly greater than dry-weather flows, use of high-rate processes requiring less tankage and space is more cost-effective than use of conventional processes.

Comparative effectiveness and cost of high-rate disinfection technologies are supported with data from pilot-scale evaluations conducted primarily on CSO at the 26th Ward Water Pollution Control Plant (WPCP) in New York City.

KEY WORDS

wet-weather flow, combined-sewer overflow, sanitary-sewer overflow, stormwater, disinfection, oxidation, ozonation, chlorination/dechlorination, irradiation, pathogens, indicator microorganisms

INTRODUCTION

The National CSO Control Policy requires disinfection after primary treatment in areas where disinfection is required by local authorities. Conventional municipal sewage disinfection processes generally use chlorine (Cl_2) gas or sodium hypochlorite (NaOCl) due to their rapid oxidation capabilities and relatively low cost. Disinfection of CSO and SSO is generally practiced to control the discharge of pathogens and indicator microorganisms in receiving waters. CSO and SSO have the characteristics of being intermittent and having high flow rate, high suspended solids (SS) content, wide temperature variation, and variable microorganism quality.

Therefore, the disinfectant used at a facility for treatment of CSO and SSO should be adaptable to intermittent use and to treatment of flows of variable quality and quantity. Other considerations include the disinfection effectiveness, oxidation/disinfection rate, and the safety and ease of feeding. Cl_2 and hypochlorite (OCl^-) will react with ammonia (NH_3) to form chloramines and react with phenols to form chlorophenols. These are toxic to aquatic life. The adverse impacts associated with chlorination are among the issues leading to the need for development of alternative methods of disinfection.

Newer disinfection technologies such as ClO_2, O_3, UV, and E-Beam have a far lesser potential to generate toxic byproducts. ClO_2 does not react with NH_3 and completely oxidizes phenols. O_3 is also effective in oxidizing phenols. UV disinfects water and wastewater by altering the genetic material (DNA) in cells so that microorganisms can no longer reproduce. UV disinfection does not generate any toxic byproducts but is affected by high SS content. E-Beam achieves effective pathogen kill, does not generate any toxic byproducts, and is not effected by SS content. Effectiveness of the new disinfection processes needs to be verified by pilot testing on wet-weather flow or on wastewaters with similar characteristics to WWF.

Since CSO and SSO flow rates and volumes are significantly greater than those of dry-weather flows, use of high-rate processes requiring less tankage and space is more cost-effective than use of conventional processes. The need for advanced technologies evolves from the National CSO Control Policy that requires treatment at the existing wastewater treatment plants (WWTPs) and at satellite locations at outfall points during the high flow periods. A similar requirement can be extended to SSO. The objective of these technologies is to secure treatment effectiveness of the plant at the increased throughput, which cannot be accomplished with the use of conventional technologies. High-rate disinfection, i.e., decreased disinfection contact time, can be accomplished by:

- increasing mixing intensity,
- increasing disinfectant concentration,
- using faster-acting oxidants, UV, E-Beam irradiation, and/or
- using combinations of these.

Use of increased mixing with any disinfection technology provides better dispersion of the disinfectant and forces disinfectant contact with a greater number of microorganisms per unit time. The increased rate of collisions decreases the required contact time, which enables a high-rate disinfection (Field *et al.*, 1996).

NEW HIGH-RATE DISINFECTION TECHNOLOGIES

Disinfection processes based on the use of ClO_2, O_3, UV, and E-Beam can accomplish high-rate treatment because they provide greater and faster microbe-killing power than conventional chlorination/dechlorination. E-Beam technology has been in commercial use in other applications, such as food processing and hazardous waste treatment, but is considered new for CSO and SSO. However, chlorination processes, considered here as conventional, can also be optimized to accomplish high-rate treatment. Chlorination, especially when followed by dechlorination, maintains its competitive edge over the newer disinfection technologies (Field and O'Connor, 1997).

ClO_2 - a yellowish gas at room temperature, is an effective disinfectant for the destruction of pathogens and inactivation of viruses. Compared to chlorine, ClO_2 is 10 times more soluble in water, is stable in water solutions, does not react with nitrogenous compounds, is effective over wide pH range, and is effective over longer periods. ClO_2 is generated onsite from sodium chlorate ($NaClO_3$) by solution processes or from sodium chlorite ($NaClO_2$) with the use of Cl_2 gas. A new aqueous UV process generates ClO_2 from $NaClO_2$ directly in UV-light reaction cells. The UV ClO_2 generator is particularly attractive in an urban setting by eliminating the need for transport and handling of Cl_2 gas.

Sequential addition of Cl_2 followed by ClO_2 at intervals of 15-30 seconds enhances high-rate disinfection beyond the expected additive effect. A minimum effective combination of 8 mg/l of Cl_2 followed by 2 mg/l of ClO_2 showed disinfection effectiveness equal to 25 mg/l of Cl_2 or 12 mg/l of ClO_2 when used individually.

O_3 - a gas, is formed by electrical discharges in the presence of oxygen and is a very powerful oxidant and disinfectant. Because O_3 disinfects more rapidly than Cl_2, it requires shorter contact time and requires smaller and less expensive contact chambers. O_3 is highly unstable, must be generated onsite just prior to application, and must be quickly and efficiently contacted with the treated flow. Dosage and contact time requirements depend on the characteristics of the flow but are usually 1-10 mg/l and < 15 minutes. Ozonation produces some byproducts but no chlorinated hydrocarbons and no residual O_3. In general, O_3 systems have relatively high capital and energy costs.

UV - light disinfects flows at the germicidal wavelength of 254 nanometers (ηm) by altering the genetic material (DNA) in cells so that microorganisms can no longer reproduce. In UV disinfection systems, the UV lamps are submerged in either a closed vessel or an open channel. Thin film flows past the UV lamps and for a few seconds the microorganisms are exposed to a dosage of UV energy. UV performance and lamps fouling depend on flow characteristics, such SS concentration and particle size distribution, presence of other UV absorbing compounds, and concentration of microorganisms. Of the various alternatives to conventional chlorination/dechlorination for the disinfection of WWFs, UV has been the most widely tested.

E-Beam - a stream of high-energy electrons is directed into a thin film of water or sludge. The electrons break apart water molecules and form highly reactive species, namely the oxidizing hydroxyl radical ($OH^{\bullet}$), the reducing aqueous electron (e-aq) and hydrogen atom ($H^{\bullet}$). Reactions of these intermediates with contaminants and microorganisms occur at diffusion-limited rates, and the treatment is complete in less than one-tenth of a second. Processes based on the electron beam irradiation principle have been used in the food preparation/packaging industry and for disinfection of wastewater treatment sludges. The E-Beam technology has been demonstrated for treatment of hazardous organic compounds that are either dissolved or suspended in groundwater or wastewater. The E-Beam process has the potential to deactivate a wide range of pathogens in a very short contact time and should penetrate turbid flows with high solids concentration as well. However, testing of this technology for WWF is very limited and there are some concerns with safety and cost (Camp Dresser & Mc Kee and Moffa & Associates, 1998).

Rapid mixing - in combination with any disinfection technology is a critical parameter, particularly when desired contact times are less than 10 minutes. Mixing provides better dispersion of the disinfectant and assures contact of the disinfectant with a greater number of microorganisms per unit time. Mixing can be accomplished by mechanical flash mixers at the point of disinfectant addition, at intermittent points, or by specially designed plug flow contact chambers containing closely spaced, corrugated parallel baffles that create a meandering path for the flow (Glover, G.E., 1973).

PILOT TESTING OF HIGH-RATE DISINFECTION TECHNOLOGIES ON CSO

Project Team

The above described four high-rate disinfection technologies have been recently pilot-tested by the New York City Department of Environmental Protection with contractors Camp, Dresser & McKee (CDM) and Moffa & Associates. For testing of the E-Beam pilot, the above affiliates were joined by the New York Power Authority of New York, NY. In August 1997, CDM entered into a contract with the U.S. Environmental Protection Agency (EPA) for pilot testing of a UV-light generated ClO_2 system, that has not been tested before, and for additional testing of the UV technology as well. The EPA-CDM project will be a part of a much larger pilot program, which will involve all of the above affiliates again (Camp Dresser & Mc Kee and Moffa & Associates, 1997 and 1998).

Pilot Facilities and Operation

The completed pilot testing of ClO_2, O_3, UV, and E-Beam high-rate systems and of a chlorination/dechlorination unit, was performed at the 26th Ward WPCP, which will also be the site for the forthcoming testing of the UV-light generated ClO_2 and UV. The purpose of the pilot study was to evaluate performance of disinfection technologies that are alternative to chlorination/dechlorination for a possible selection to be used as a suitable alternative at the Spring Creek Auxiliary Wastewater Pollution Control Plant (AWPCP), an off-line CSO storage facility.

Pilot testing was designed to subject the selected four disinfection technologies to a wide range of influent quality typical of CSOs and to compare the technologies for their relative effectiveness in decreasing bacteria throughout the range of water quality. Four indicator bacteria were used as a measure of each technology effectiveness: total coliform, fecal coliform, *Escherichia coli (E.coli)*, and enterococcus. Bacteria kills, in terms of log reduction and effluent concentration, were related to the disinfectant dose for each of the technologies. To evaluate performance of technologies, a satisfactory disinfection effectiveness was defined as 3 to 4 log bacterial reduction.

Pilot test runs for ClO_2, O_3, UV, and chlorination/dechlorination were performed from December 17, 1996 through March 12, 1997. The pilot units were located side-by-side for concurrent operation. A total of 16 test runs were performed during both dry and wet weather. The E-Beam pilot testing was performed from February 24, 1997 through March 26, 1997. A total of 20 test runs were performed.

Wastewater flow to the pilot facility was supplied from either the primary settling tank influent or the primary settling tank effluent to assure a wide range of water quality. Wastewater feed and effluent piping was sized to provide a minimum flow velocity of 2 ft/sec to prevent solids deposition. Each pilot system was subjected to the same wastewater to compare the performance of one directly against the other.

The disinfection pilot units used in the study were:

<u>ClO_2</u> The contact /treatment skid was provided by UVD Inc. of Syracuse, NY and included the contact tank, mixer, and residual instrumentation. CDG Technology of New York City, NY provided the onsite ClO_2 generator. The tank was sized to provide a detention time of 5 minutes at 50 gpm.

<u>O_3</u> The O_3 unit was a trailer mounted system manufactured by Aquifine Wedeco Environmental Systems, Inc., (AWES), of Valencia, CA. O_3 was generated onsite and on-demand using 90% pure oxygen and a corona discharge type O_3 generator. The tank was sized to provide a minimum detention time of 10 minutes at 10 gpm.

<u>UV</u> The UV unit was provided by Aquionics, Inc., of Erlanger, KY. The unit was a medium pressure, high-intensity type. Manually controlled flow to the unit varied from 75 to 250 gpm.

<u>E-Beam</u> The E-Beam pilot unit was developed by High Voltage Environmental Applications (HVEA) of Miami, FL. The unit was housed in a trailer equipped with an electric generator to provide the necessary power (500 kV differential) to operate the system. The unit operated at a flow rate of 20 gpm during runs 1 through 4 and 10 gpm during runs 5 through 20.

<u>Chlorination/Dechlorination</u> The unit, provided by UVD Inc., was a skid mounted system consisting of chlorination and dechlorination 250 -gall contact tanks with mixers, chemical tanks with solenoid metering pumps, and residual instrumentation.

Results

<u>Dose-Response Relationships</u>

All technologies achieved bacterial reductions of 3 to 4 logs. ClO_2 , O_3, and chlorination/dechlorination achieved these levels over a full range of wastewater quality tested. UV showed lower effectiveness at SS concentrations above 150 mg/l.

Disinfection doses required to achieve a 4 log reduction of fecal coliform and of fecal coliform effluent concentrations < 1,000 cfu/100 ml, for ClO_2, O_3, UV, and chlorination/dechlorination, were found to be 8 mg/l, 40 mg/l, 55 mWs/cm^2, and 20 mg/l, respectively. The E-Beam did not achieve the 4 log bacterial reduction during any run and the disinfection levels did not appear to be a function of disinfection dose, wastewater quality, or delivery configuration.

Differing sensitivities of bacterial groups to each disinfection treatment

In the case of:

ClO_2 - enterococci showed a greater susceptibility and less variability in concentrations between 6 and 10 mg/l than did fecal coliform

O_3 - there were only minor differences between fecal coliform and enterococci

UV- enterococci showed a greater susceptibility than did fecal coliform and there was less variability in concentration

E-Beam - no trend was observed but effluent fecal coliform and *E.coli* were below the 1,000 cfu/100 ml effluent target for 25% of samples

Chlorine - enterococci showed a greater susceptibility between doses of 16 and 24 mg/l than did fecal coliform

Effect of Wastewater Characteristics on Technology Performance

In case of UV the effect of SS at concentrations > 150 mg/l decreased the disinfections efficiency. However, there is limited data on UV performance at SS concentrations higher than 150 mg/l. The remaining technologies showed no apparent trend of reduced disinfection effectiveness with increased SS concentrations.

Reliability of the Units

The ClO_2, UV, and chlorination/dechlorination units showed a reliable performance. The O_3 pilot was slightly less reliable. The E-Beam unit was not designed for testing of CSO that contains particulate matter. The unit's delivery system was found to be clogging with solids and did not allow for sufficient electron penetration throughout the entire contact area. An increase in energy (dose) did not show increased disinfection efficiency. It is likely that a portion of the wastewater was not treated. As a result, this test did not show the full potential of E-Beam technology for disinfection.

Cost Comparison and Energy Use

In this study the cost comparison of disinfection systems tested was tailored for application to the Spring Creek AWPCP. It appears that chlorination/dechlorination and ClO_2 are most cost effective for this facility. E-Beam, UV, O_3, ClO_2, and chlorination are listed in order of decreasing energy use.

FUTURE NEEDS (Field *et al.*, 1996, Field and O'Connor, 1997)

Pilot Testing

- Pilot testing of improved disinfection technologies, such as the UV-light generated ClO_2 system, on CSO and SSO

- Evaluate the effects of adequate mixing on performance of disinfection technologies
- Develop realistic and thorough cost estimates for new disinfection technologies
- Repeat pilot testing of E-Beam technology with equipment suitable for WWF

Research

- Evaluate byproducts of disinfection for promising technologies
- Evaluate potential for bacterial regrowth following disinfection
- Evaluate development of viral indicators in addition to bacterial indicators for determining disinfection effectiveness
- Evaluate effect of particle occlusion as impairment of disinfection efficiency since microorganisms can be contained or occluded inside larger protective solid particles

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The Effectiveness of Freshwater Wetlands for Nonpoint Source Pollution Control in the Rouge River Watershed.

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ABSTRACT

The Rouge River National Wet Weather Demonstration Project (RPO) is a federally funded initiative with the objective of developing demonstration projects to evaluate a variety of urban nonpoint source pollution (NPS) reduction best management practices (BMPs) for the Rouge River watershed. These demonstrations will in sum improve the quality of storm water runoff to the Rouge River. The function of wetland filtration for water quality improvement has been recognized as one potential BMP.

Wetlands increase storm water detention capacity, increase storm water attenuation, moderate low flows, and improve water quality by removing nutrients, sediments and metals. The goal of this wetland demonstration project was to evaluate the effectiveness of freshwater wetlands in the treatment of storm water. The wetland demonstration project (WETL-1) utilized existing, enhanced, and created wetlands to demonstrate the value and effectiveness of wetlands in treating storm water runoff. Future evaluations will identify pollutants removed by the demonstration wetlands, the efficiency of the removal processes and the effects of sediments on this removal efficiency.

This manuscript summarizes the WETL-1 activities including wetland design, construction, and monitoring required to implement the Rouge River wetlands demonstration project.

KEYWORDS

storm water, wetlands, forested wetlands, runoff treatment, water quality

INTRODUCTION

The Rouge River National Wet Weather Demonstration Project is a federally funded initiative with the objective of developing a wet weather management plan for the Rouge River watershed that will improve water quality. The project includes a variety of demonstration projects which, in sum, will improve the quality of storm water runoff to the Rouge River. The Rouge project includes a variety of demonstrations of urban Nonpoint Source Pollution (NPS) reduction methods known as best management practices (BMP's). These methods include structural controls, source controls, treatment of impoundment sediments, detention basins, public participation and wetland treatment. This report summarizes the activities associated with the WETL-1, wetlands demonstration project.

The Rouge River, located in southeast Michigan, runs through the most densely populated and urbanized land area in the state. It is approximately 465 square miles and includes 48 municipalities in three counties, with a population of 1.5 million people. Pollution is a significant problem throughout the Rouge River Watershed. The State of Michigan Water Resources Commission has indicated that the water quality of the Rouge severely impairs the designated uses of the river, including recreation, water supply, aesthetics, and aquatic organisms.. The demonstration projects, in sum, will improve the quality of storm water runoff to the Rouge River and hopefully reinstate the River' designated uses.

JJR incorporated in association with Tilton & Associates worked together to develop a demonstration project to evaluate whether wetlands can be used as a low cost alternative to treating pollutants from storm water runoff. The alternative is one of the best management practices that the Rouge River Wet Weather Demonstration Project is interested in evaluating. The project is a demonstration of using existing, restored and created freshwater wetlands to control pollution from nonpoint source discharges. Wetlands are known to improve water quality by increasing storm water attenuation, moderating low flows, and removing nutrients, sediments and metals. This demonstration project will compare the pollutant removal effectiveness from storm water for four different types of wetlands systems that occur in the landscape: 1) an existing forested wetland; 2) an existing wetland system that supports a combined forested, emergent and scrub/shrub; 3) a newly created emergent wetland; and, 4) a mature created emergent/shrub/scrub wetland system.

Four wetland areas were identified within the City of Inkster, north of Michigan Avenue between Inkster and Henry Ruff Roads. The design of the wetland projects as storm water pollution control sites incorporated features that allows for the manipulation of storm water flow, quantity and duration, and provides direct comparison of the effectiveness of pollution control in each of the wetland types. The contributing storm sewer drainage for each site was defined and modeled so that the effect of a given wetland area on water quality and quantity can be determined. Design criteria were developed from the modeled hydrological data in combination with characteristics of the available treatment area. Common elements of the design included the incorporation of a sediment forebay to filter the large particles before the storm water enters the wetland system; treatment of "first flush" for most storm events; engineered discharge outlets to the Rouge River with monitoring capabilities; and intermediate monitoring points where applicable..

METHODOLOGY

Although past storm water management designs utilized natural wetlands to treat storm water, regulatory agencies discouraged this approach. This position is primarily a function of jurisdictional policy implemented against poorly designed systems that have traditionally impaired the functional uses of natural wetlands. There is a lack of research on the quantity and quality of storm water that natural wetlands are capable of treating without being negatively impacted. Constructed wetlands in contrast, are being built specifically for treating point source discharges and storm water runoff. Consequently there is no intention of replicating ecological functions other than water quality treatment. Only a few examples of wetland BMP's occur in the Rouge River watershed.

The RPO included a demonstration of nonpoint source control from the use of existing, restored and created freshwater wetlands (WETL-1). The overall nonpoint source pollution (NPS) control strategy of WETL-1 has been documented in various publications available at the Rouge Project Office (RPO). The strategy consisted of demonstrating: 1) a site selection process that emphasizes the potential for integrated solutions, *"Selection of Appropriate Wetland Nonpoint Source Pollution Abatement Locations"* (RPO-NPS-TM36.00); 2) a basis for design development that accounts for wetland habitat protection and water quality improvement goals, *"Conceptual Design of Wetland Management Systems"* (RPO-NPS-TM37.00); 3) biological and water quality monitoring program unique to wetland habitats, *"Wetland Biological Monitoring Program"* (RPO-NPS-TPM48); 4) the operation and maintenance program for the wetland systems "*Operation and Maintenance Manual Nonpoint Work Plan (WETL-1), Task No. 3* (RPO-

NPS-TPM37.00). The current status of the wetland project of the RPO is that site selection, design development, monitoring plans and construction documents have been completed. Construction of the wetland projects was virtually completed in November 1996 and preliminary water quality monitoring data is now becoming available.

The intent of the WETL-1 project was to increase storm water detention capacity by utilizing wetlands in the Rouge River watershed. Wetlands increase storm water attenuation, moderate low flows, and improve water quality by removing nutrients, sediments and metals. The future goal of this demonstration project is to evaluate the effectiveness of the demonstration wetlands in the treatment of storm water. This evaluation will include identification of pollutants removed by the demonstration wetlands, the efficiency of the removal processes and the effects of sediments on this removal efficiency. Ultimately, the demonstration project will compare the pollutant removal effectiveness of different types of wetlands:

- An existing forested wetland;
- A mixed forested, open water and scrub wetland system;
- Newly created emergent wetland; and,
- A mature created emergent/shrub/scrub wetland system.

The basis for design of NPS control wetlands, regardless of whether the wetlands are existing, restored or created, presents an integrated approach that accounts for wetland ecology, wetland hydrology, water quality considerations, watershed characteristics and surrounding land use. Utilizing these guiding principles, a selection process was initiated to identify appropriate sites for wetland demonstration projects.

Site Selection Process

As part of this project, an extensive investigation was completed to identify and select appropriate wetland sites in the watershed where pollution abatement was feasible and prudent. The investigation included collecting relevant information to aid in the search for targeted wetland sites. The information included Michigan Resource Information System (MIRIS) maps, National Wetlands Inventory maps, soil maps, aerial photography, land use maps, recreation maps, Wayne County Rouge Program Office (RPO) Geographic Information System (GIS) mapping of storm water discharges, and existing and historical drainage maps. Utilizing this information, potential sites were field surveyed. The sites included existing constructed wetlands, naturally occurring wetlands, potential Combined Sewer Overflow (CSO) sites for constructing new wetlands, and sites draining approximately 100 acres where wetlands could be restored.

This investigation also included a review of the existing information on site specific wetland ecology, wetland ecosystem processes, and the use of specific wetland sites for the control of storm water. A review of the wetland types and existing plant communities existing in the watershed identified four wetland types: forested wetlands, wet meadows, scrub-shrub and shallow water wetlands. These Rouge River wetland types periodically flood with nutrient-enriched waters.

A total of 25 sites (9 constructed, 13 existing, and 3 CSO) were considered as potential nonpoint source abatement locations. Five Areas were selected (3 existing and 2 constructed wetlands) as prudent and feasible for further consideration. Technical Memorandum, *"Selection of Appropriate Wetland Nonpoint Source Pollution Abatement Locations"* *(RPO-NPS-TM36.00)* is available from the Rouge Program Office for review. These Areas are located within the City of Inkster, north of Michigan Avenue between Inkster and Henry Ruff Roads. A created wetland built approximately eight years ago in West Bloomfield Township has also been selected to evaluate and compare its effectiveness with newly created wetlands.

Wetland Design Development

The design of the wetland projects as NPS control sites incorporated features that allows manipulation of storm water flow quantity and duration, and allows for the direct comparison of the effectiveness of NPS control in existing and created wetlands receiving storm water runoff from a single watershed. Design criteria for each of the wetland areas were developed from modeled hydrological data in combination with characteristics of the available treatment area. The wetland creation and enhancement areas contain similar design elements that provide comparable experimental data which can be related to known design parameters. These elements include the incorporation of a sediment forebay to filter the large particles before the storm water enters the wetland system; treatment of "first flush" for most storm events; designed discharge outlets to the Rouge River with monitoring capabilities; and, intermediate monitoring points where applicable. The contributing storm sewer area for each area has been defined and modeled so that the effect of a given wetland area on water quality and quantity can be determined. The influence of directly adjacent land is assumed to be negligible.

Design Characteristics of Wetland Area 1. Wetland Area 1 is designed to demonstrate the efficiency of storm water treatment by a newly created emergent wetland. Approximately 3.0 acres of emergent wetland was designed and constructed to receive storm water from an approximately 48 acre older residential neighborhood. Storm water from the storm sewer area was being discharged through a short swale directly connected to the Rouge River. The design elements of Area 1 includes a sediment forebay, designed to capture the storm water flowing from the existing 42-inch storm. All of the storm water from each rain event is directed to the wetland system via the sediment forebay and a vegetated swale.

Soil boring information was acquired to document and test wetland creation designs with varying soil types. Area 1 was evaluated to determine the need for a clay liner in sandy soils, soil fertility, soils in direct contact with ground water, etc. An outlet structure was designed that included a manhole for the installation of water quality and flow monitoring equipment. Manipulation of flow rates and retention periods may be discontinued at the end of the demonstration period. The wetland area however has been designed to be sustained by the contributions from the existing storm sewer area. This area will continue function as an emergent wetland after completion of the demonstration project

Design Characteristics of Wetland Area 2. Among the demonstration sites the project selected two forested wetlands. These were selected to demonstrate the effectiveness of this type of wetland in controlling NPS control. The majority of the existing wetland habitat in the Rouge River watershed is forested and forested wetlands are common in certain parts of the world. The demonstration of the effectiveness of forested freshwater wetlands in control of NPS pollution is critical to the long-term implementation of a wetland component in a comprehensive NPS management strategy. Forested wetlands, as NPS control sites have not been widely studied, although emergent and open water systems have been studied and are utilized much more frequently. One of the more frequent negative environmental impacts of the use of forested wetlands is flooding and destruction of tree species and subsequent loss of forested wetland habitat. The site selection methodology and basis for design of the forested wetland basins were adapted to account for the sensitive nature of these wetlands and the hydrologic impacts of using forested wetlands will be assessed. Demonstrating the use of forested wetlands as effective NPS control sites and, perhaps more importantly, demonstrating the design elements necessary to protect forested wetland habitat from adverse impacts associated with NPS control is one benefit of the demonstration project.

Wetland Area 2 is proposed to demonstrate the efficiency of storm water treatment by an existing forested wetland. Approximately 3.0 acres of forested wetland has been enclosed by small berms designed to retain a specified amount of storm water from the storm sewer area. Storm water from approximately 165 acres of mixed land use has historically been discharged directly to the Rouge River via a 60-inch pipe. Area 2 wetland utilizes a lift station to deliver a specified portion of the storm water from the storm sewer to the wetland. Storm water is transported to the wetland area from the storm sewer via an underground pipe into a catch basin designed to function as a sediment forebay. Both the pipe and catch basin are constructed in an upland area. The wetland area is enclosed by a berm along the northern boundary of the site to isolate it to a known and measurable area. This berm runs parallel to the Rouge River and is set at an elevation of 610 which will be crested by 100 year flood waters from the Rouge River.

This wetland previously discharged water to the Rouge River at one location situated at the far eastern point of the site. Overflow from wetland Area 2 will continue to discharge from this location. The outlet has been modified to control the outflow rate and allow for monitoring activities. Minor grade modifications were necessary for the installation of a weir and valve to control outlet flow levels. The low point of the weir has been set to retain water within the wetland and slowly release it to the Rouge River.

Design Characteristics of Wetland Area 3. Area 3, is also located south of the Rouge River between Inkster and Middlebelt Roads, approximately 1,800 feet west of Area 2. The entire site is within the 100 year floodplain of the Rouge River. The site is bisected by an 80 foot long channel which currently conveys storm water runoff from the 183 acre, residential and commercial watershed directly to the Rouge River. The ditch has partially filled with sediments resulting in some storm water flow being diverted to the wetlands on the east and west sides of the ditch. The 4.7 acre wetland on the east side of the ditch contains forested/scrub/shrub/emergent and open water communities. Existing vegetation includes willow, cattail, water plantain, elm, cottonwood, sedges, rushes and snags. Water discharges from this wetland to the river through a shallow swale along the site's eastern river bank.

Approximately 2.4 acres of emergent/scrub/shrub wetland are located along the west side of the ditch. This wetland also receives storm water from the existing sewer line due to the clogged ditch. This wetland contains primarily willow, dogwood and cattail. While no detailed hydrogeologic data has been collected, moderate base flow in the ditch indicates groundwater may also contribute to the wetland hydrology.

Wetland Area 3 contains two separate treatment areas, 3-East and 3-West. A sediment forebay is located at the inflow of each wetland area. Three outlets were constructed in this basin to direct first flush and small storm event flow to wetlands 3-East and 3-West, and overflow from larger storms is discharged directly to the Rouge River through an existing swale.

Wetland Area 3-East is an existing wetland system that supports forested, emergent, scrub/shrub, and open water systems. The objective of the design is to enhanced the flow through this wetland to utilize each of the wetland types in the treatment of storm water. The designated area is enclosed by eighteen inch berms. Storm water flow from the sediment forebay is discharged into the existing wetland. A containment berm was constructed along the northern portion of the wetland area. Within the wetland the flow achieves a maximum flow length ratio and utilizes various wetland types in the treatment train. Berms do not impede the 100 year flood flow from the Rouge River flood conditions. Area 3-East drains to the Rouge River at a low point located along the eastern boundary. Overflow from this area will continue to discharge from this location. The outlet has been modified to control the flow rate and allow for monitoring activities

Wetland Area 3-West contains an emergent and scrub/shrub wetlands created within a former upland area. The created wetland was apportioned into two areas; one and two acre wetland cells. Flow from the sediment forebay is released directly into this one acre wetland. The succeeding wetland is approximately two acres in size. This sizing allows for an assessment of water quality treatment from specified areas of created wetland. The water flows through this two tier system to an outlet to the Rouge River. This outlet is located at a naturally occurring low point within the forested wetland along the River's banks. A controlled outlet structure was installed at the outlet point to control retention time, water depth and allow for monitoring activities. These wetlands are created in conjunction with wetland mitigation; therefore, they are designed to function as wetlands with minor modifications, if any, after the demonstration is completed.

Construction of the Wetland Project. Construction documents and specifications for the construction of these projects were completed in November 1995. Bidding and award of the projects allowed construction to begin in February, 1996. Construction was substantially complete in November 1996. The construction schedule for these projects was extended by approximately five months. Various reasons accounted for project delays including; spring flooding of the Rouge River, vandalism of power supply panels, delays in equipment orders, unknown utilities encountered and land owner disputes. The operation and maintenance of this wetland demonstration project requires regular inspections of earthwork, landscaping, structural components and other aspects of distribution system. The construction contractor as part of the contract has provided this task. An *Operation and Maintenance Manual* (RPO-NPS-TPM37.00) was prepared for the wetland projects. A written summary of Operations and Maintenance activities is provided on an annual basis.

RESULTS

Initial data results are now being reported. The following tables represent the average of six wet weather events collected from September 1996 to September 1997: Table 1) West Bloomfield Wetland, a mature created wetland; Table 2) Wetland Area 2, forested wetland and Table 3) Wetland Area 3 East, a mixed community wetland. The results indicate that nearly every measured pollutant of storm water was significantly reduced through the wetland treatment system. Nitrate and nitrite nitrogen removal percentages ranged from 22 to 53 percent; Total Phosphorus removal efficiency ranged from 11 to 43 percent; Total Suspended Solids were reduced from 63 percent up to 86 percent; and heavy metals removal percentages were reported from 10 percent to 73 percent reduction. In a few cases some parameters increased, most notably ammonia nitrogen, total kjeldahl nitrogen and orthophosphate. The averages for these parameters were elevated primarily due to late summer sampling events when plant die-off and decomposition skewed the results. The summary of the results reported thus far are typical of what has been reported in the literature for wastewater treatment wetlands (Hammer and Kadlec, 1983). All of the wetlands will continue to be monitored for the next five years including the forested and enhanced wetland systems. The results will be tabulated and published through the Rouge Program Office and will be presented on the Internet Web Page at the RPO.

Table 1
Rouge River National Wet Weather Demonstration Project
Pollutant Removal Effectiveness
West Bloomfield Wetland

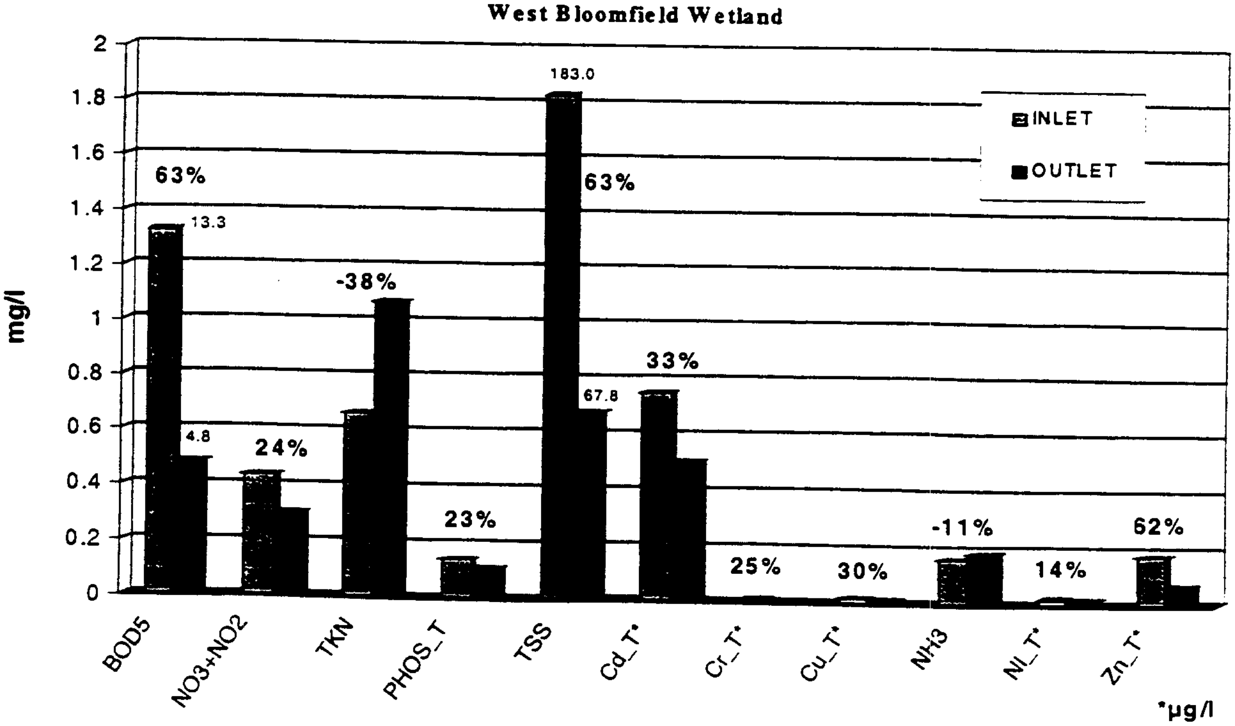

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Table 2
Rouge River National Wet Weather Demonstration Project
Pollutant Removal Effectiveness
Inkster Wetland Area 2

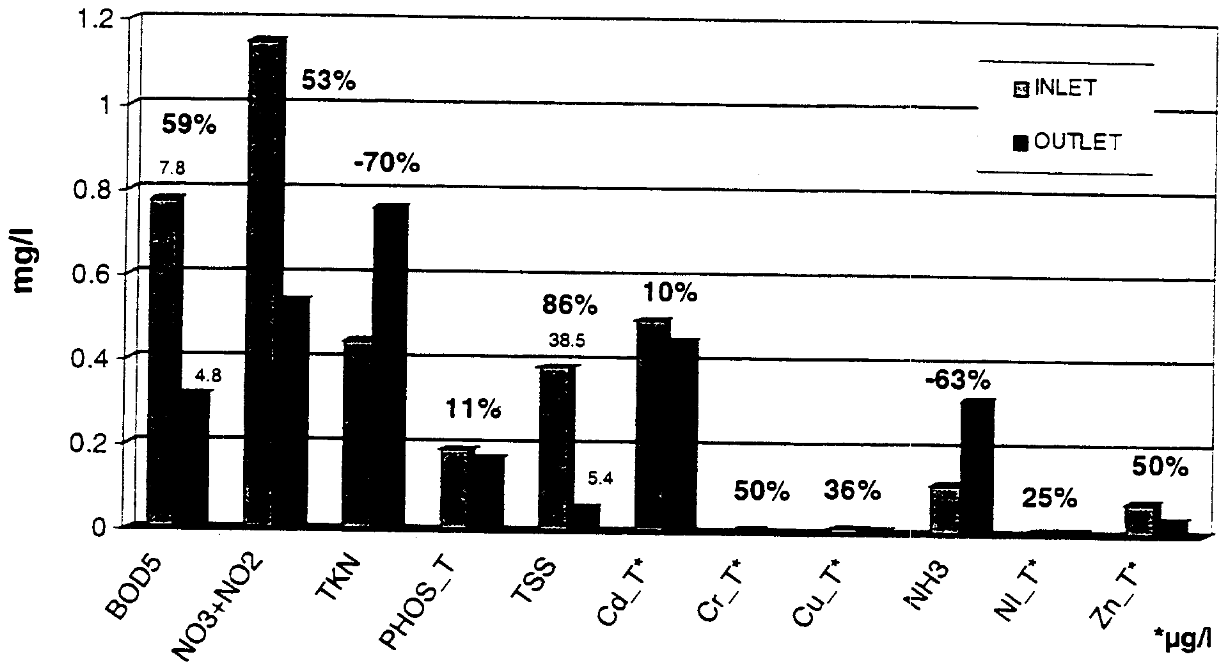
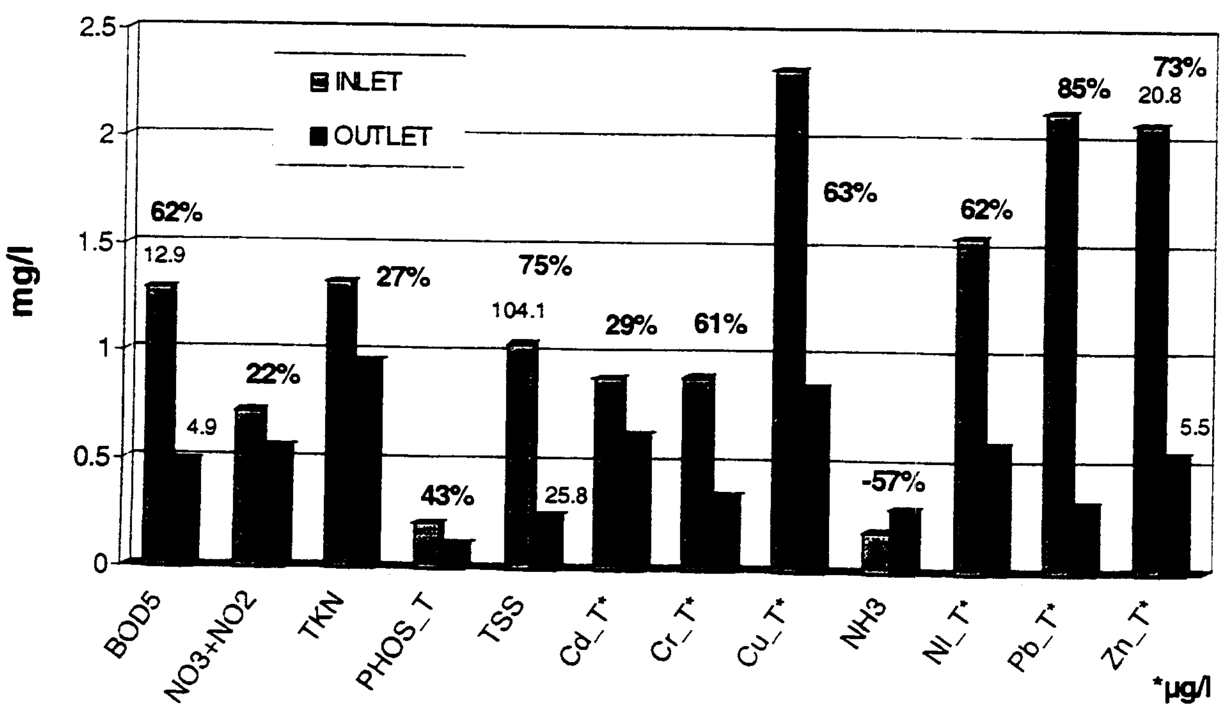


Table 3
Rouge River National Wet Weather Demonstration Project
Pollutant Removal Effectiveness
Inkster Wetland Area 3 East



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DISCUSSION

The use of wetlands for wastewater treatment has been researched for approximately twenty years. The results of this body of information define the effectiveness of wetlands in pollutant removal efficiency in wastewater treatment systems. However, this information may not be directly applied to the use of wetlands for nonpoint source treatment systems. Specifically, the two systems are different in hydrology, pollutant loading, pollutant characteristics, and operation and maintenance practices. Wastewater treatment wetlands tend to receive a constant flow of water whereas storm water systems receive pulse loading of storm water with inconsistent pollutant levels. Typical pollutant removal rates reported in the literature for wastewater systems include: 75-93 percent for Total Suspended Solids; 70-90 percent for BOD; 30-50 percent for total phosphorus; and 75-95 percent for total nitrogen.

Under the Clean Water Act, the EPA has responsibilities for wetland protection and specifically for regulation of discharge of waterborne pollutants (Section 401 and 402). The use of natural wetlands has been a source of controversy for receiving storm water runoff. The EPA does not support the use of natural wetlands for treating storm water due to the potential ecological and environmental degradation of the wetland. This position is primarily a function of jurisdictional policy implemented against poorly designed systems that have traditional impaired the functional uses of natural wetlands. There is a lack of research on the quantity and quality of storm water that natural wetlands are capable of treating without being negatively impacted. The use of natural wetlands in treating storm water may be considered, particularly in an urban setting if; 1) other treatment options are limited; 2) the existing wetland has been disturbed or degraded thereby limiting its plant and animal diversity; 3) the existing wetland is small, isolated, and incidental compared to the watershed area; or 4) the existing wetland could be enhanced by increasing the amount of flow and increasing its biodiversity.

This project has only begun to evaluate the effectiveness of freshwater wetlands in treating storm water runoff. To date only a limited number of sampling events have occurred and in the case of Wetland 3 West, a newly created wetland, sampling will begin in the spring of 1998. Future evaluations will quantify the pollutants removed by the demonstration wetlands, the efficiency of the removal processes, direct comparisons of pollutant removal efficiencies for different wetland types and the effects of sediments on this removal efficiency. Biological monitoring running concurrent with the water quality monitoring will closely monitor the wetland ecosystem as the project progresses. In addition, tissue analysis is being proposed on aquatic organisms to determine if bioaccumulation of heavy metals should be of concern in wetland treatment systems.

CONCLUSIONS

The initial results look promising as the natural wetlands and created wetlands are removing a significant amount of pollutant loading that would otherwise be discharged to the Rouge River. Future strategies that would consider the incorporation wetland treatment systems into a storm water management plan should be seriously considered.

Assessments of the benefits relative to these wetland systems will be provided on an annual basis for five years in separate biological and water quality monitoring report. Three annual biological monitoring reports, RPO-NPS-TPM48.00, RPO-NPS-TPM48.01 and RPO-NPS-TPM48.02 (pending) have been prepared to develop baseline information. Direct assessment of pollutant removals started in the spring of 1997 when the wetland water quality-monitoring program was implemented and initial data results reported. Preliminary assessments indicate that the hydrology of the existing forested wetlands has been slightly modified during the study. In anticipation of this altered hydrology a tree survey was completed as part of the biological monitoring report. All trees greater than six inches were surveyed using GPS technology. The trees identified exhibit a wide range of tolerance to inundation. Therefore, it is not anticipated that the altered hydrology will greatly affect the wetland areas. The volume of water flowing through the systems is being monitored and controlled so as not to be significantly different from the pre-construction condition. The wetlands will continue to be monitored closely to ensure the existing function and structure are not impaired.

ACKNOWLEDGMENTS

We would like to thank representatives from Wayne County Department of the Environment, Rouge Program Office staff, and the U.S EPA for their assistance in the implementation of this wetland demonstration project. The Rouge River National Wet Weather Demonstration Project is funded, in part, by the United States Environmental Protection Agency (EPA) Grant #X995743-01, #X995743-01, #995743-03 and #C995743-01. The views expressed by the authors are their own and do not necessary reflect those of EPA.

Costs associated with the construction and monitoring of the existing wetland projects were borne by money made available through Rouge River Demonstration Funds as approved by the EPA Region V, MDEQ, and Wayne County. In addition to the two forested wetland areas, two created wetlands were developed under grant money designated for wetland creation within the Rouge River watershed. The money was designated under an MDEQ permit which required Waste Management of Michigan, Inc. (WMI) to provide Wayne County a grant to create wetlands within the Rouge River watershed for the purpose of providing water quality improvement to the Rouge River (RPO-NPS-TM35.00).The created wetlands have been designed to function in perpetuity and will be monitored as required by MDEQ. In addition to monitoring the success of the wetland creation, all of the wetlands are monitored for water quality improvement by the RPO.

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CSO CONTROLS AND SUPPLEMENTAL AERATION FOR PAERDEGAT BASIN

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ABSTRACT

The New York City Department of Environmental Protection (DEP) has conducted a study to analyze the feasibility of utilizing supplemental aeration in conjunction with a combined sewer overflow (CSO) facility proposed at Paerdegat Basin, Brooklyn, NY. The goal of the study was to determine the overall cost effectiveness of limiting the amount of conventional CSO storage required, and supplementing dissolved oxygen levels within Paerdegat Basin through either in-stream or side-stream aeration.

Unlike existing current uses of aeration to supplement dissolved oxygen levels in water bodies, this study considered the technical aspects of implementing aeration within a marine environment in a narrow man-made tributary extending over a mile inland from Jamaica Bay.

In addition, original computer models and water quality projections developed for the proposed Paerdegat Basin Water Quality Facility plan were updated and run for varying levels of CSO abatement supplemented with aeration. Specifically, aeration modeling was based on the USEPAs aeration design theory, with consideration given to calculation of oxygen transfer efficiency based on receiving water conditions. Additionally, a fine-grid water quality model was developed to represent conditions within Paerdegat Basin, and assist in the design of an aeration distribution system.

Considering CSO controls and supplemental aeration analyzed in this study, a recommendation for attainment of water quality dissolved oxygen standards in Paerdegat Basin was developed.

KEY WORDS: Combined Sewer Overflows, Water Quality Standards, Water Quality Modeling, Dissolved Oxygen, Aeration

INTRODUCTION

Studies conducted by the New York City Department of Environmental Protection (NYCDEP) in the late 1970's showed that Paerdegat Basin, located in southeastern Brooklyn, New York, was severely impacted by degraded water quality conditions. Combined sewer overflows (CSOs) were identified as a major source of the pollution entering Paerdegat Basin, contributing to significant violations in the New York State Department of Environmental Conservation (NYSDEC) state water quality standards for dissolved oxygen (DO), coliforms, floatables and settleable solids.

The Paerdegat Basin Water Quality Facility Plan (September, 1991), as developed, included the reduction of CSO impacts through the maximized use of existing facilities (sewers, interceptors, and water pollution control plants (WPCPs)), and construction of a 30 million gallon (MG) off-line CSO retention tank. The resulting CSO retention facility had a capacity (in-line and off-line storage) of 50 MG.

The original CSO plan had an estimated construction cost of approximately $200M (million) and resulted in significant water quality improvements in Paerdegat Basin. Model projections indicated up to an 80% reduction in biochemical oxygen demand and suspended solids discharged. Total coliform levels would be similarly reduced by 95%. Based on these performance levels, it was projected that required DO levels would be met throughout Paerdegat Basin, except at the head end where they were projected to drop to 3.0 mg/L about 1% of the time as a result of heavy rainfall conditions. At all other times, DO levels were above the NYSDEC standard of 4.0 mg/L.

Subsequent to development of the Paerdegat Basin Facility Plan, an alternative proposal was presented by the NYCDEP in the Jamaica Bay Comprehensive Watershed Management Plan (December 1993). This alternative proposal asserted that similar water quality improvements in Paerdegat Basin could be achieved through the volumetric reduction of CSO storage capacity, while simultaneously supplementing the reduced storage volume with aeration. The proposed system was to fully comply with dissolved oxygen standards in Paerdegat Basin.

The goal of investigating supplemental aeration for Paerdegat Basin was to evaluate the technical feasibility of using aeration technologies to supplement a reduction in CSO retention volume. This paper describes the engineering evaluation that was conducted to evaluate the feasibility of applying various aeration alternatives to a revised CSO facility design at Paerdegat Basin. It was concluded from this evaluation that the reduction of CSO retention volume can be supplemented with aeration to maintain adequate levels of dissolved oxygen in the basin, and potentially reduce overall project costs.

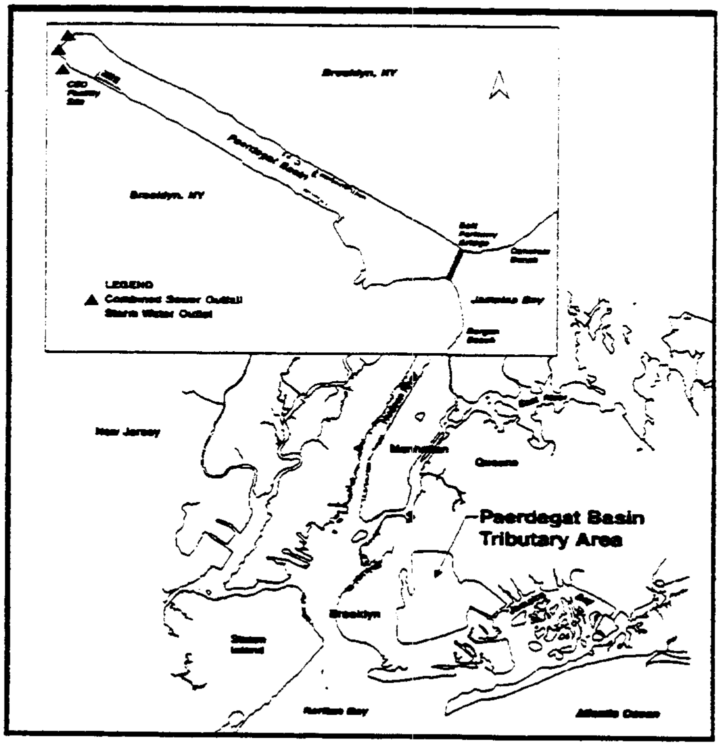

Figure 1 - Location Plan

Project Area

Paerdegat Basin is a rectangular, dead-end channel approximately 6,600 feet long, 450 feet wide at points, and varying from 1 to 16 feet in depth depending on tidal conditions. The basin is located in southeastern Brooklyn, New York and receives combined sewer overflows (CSO's) from a drainage area of approximately 6,000 acres. The basin receiving waters have been designated Class I by the NYSDEC where fishing and secondary contact recreation is its' best intended use. The NYSDEC enforces a dissolved oxygen standard of never less than 4.0 mg/L in Paerdegat Basin.

Paerdegat Basin is tributary to the larger Jamaica Bay situated to the east, where the waters are designated by NYSDEC as Class SB. Class SB waters have a higher DO standard which is never less than 5.0 mg/L. Figure 1 shows the general location of Paerdegat Basin, its proximity to Jamaica Bay, and the contributing drainage area.

METHODOLOGY

Discussion of Aeration Technologies

Several systems are currently available for the artificial aeration of natural water bodies with low DO levels such as Paerdegat Basin. Systems including direct in-stream aeration through the use of shore-mounted blowers, air distribution piping and a network of bottom-mounted diffusers were considered. Additionally, side-stream aeration systems where low DO water is pumped to a shore-side aeration tank and aerated by forced air diffusion (such as used in water treatment processes), or a cascade system were considered. Technology reviews of alternative applications currently available for aeration, including systems utilizing pure oxygen injection or ozonation were also considered.

One of the major engineering obstacles facing successful aeration of a large body of water such as Paerdegat Basin involves not only the direct application of a sufficient quantity of oxygen into the water, but also completely distributing it throughout the water column. This task was further complicated by the relatively stagnant waters of Paerdegat Basin, where complete flushing of the basin has been estimated to occur only once during a period of fourteen (14) tidal cycles.

Preliminary Evaluation of Aeration Technologies

Each of the aeration technologies identified below was subjected to a preliminary screening process. Each technology was evaluated with consideration given to cost, technological constraints, siting issues, environmental issues, community concerns, operation and maintenance, permitting, and other issues.

Aeration technologies reviewed included:

1. In-stream mechanical aeration;
2. In-stream natural aeration;
3. In-stream forced air diffusion;
4. Side-stream forced air diffusion;
5. Side-stream cascade aeration;
6. Side-stream aeration with pure oxygen, and
7. Ozonation.

In-Stream Mechanical Aeration

An in-stream mechanical aeration system consists of equipment placed on the water surface that is designed to mechanically agitate the water column. Mechanical surface aerators are conceptually one of the simplest aeration equipment presently available, which is one of their advantages over other technologies. They consist of a submerged or partially submerged impeller attached to a motor that is either anchored to the basin bottom or fixed on platforms/structures. The impellers agitate the water column vigorously while simultaneously entraining air into the water. In some cases, surface aerators are equipped with submerged draft tubes that enhance mixing by bringing liquid from the bottom of the water column up through the tube and into the aerator's impeller. It is worth noting that draft tubes are normally used where the depth exceeds 15 ft.

Another type of mechanical surface aerator is the motor-driven propeller aspirator consisting of an electric-driven propeller submerged at the end of a hollow shaft. The action of the propeller rotation draws air from the atmosphere through the shaft. Combined air velocity and propeller action creates turbulence forming small bubbles that diffuse oxygen into the water column. This type of aerator can also be floating or permanently platform mounted.

Both of the above types of in-stream mechanical aerators would require shore-side construction to locate the electric service and house the control equipment. Power to the units can be either floating or bottom run. In addition, a pullout station equipped with a crane to remove the surface aerators, and provisions to load and off-load trucks for transport to a storage/maintenance facility could also be provided.

The advantages of using mechanical surface aerators over other types of aeration for Paerdegat Basin is that they are relatively simple to operate, and have a good maintenance record. They can also be taken off-line easily and spare units activated if necessary. They also have the capability of operating under changing process conditions and have excellent mixing action.

Disadvantages include the mooring system requirements, the shore-side support facility required, the power distribution to the individual units, and the impact on the basin's accessibility for recreational boaters. The impact on basin's accessibility resulting from the floating units is considered a major disadvantage to the ultimate goal of the water quality restoration of Paerdegat Basin and its use as a passive recreational water body. As a result, the use of mechanical aerators for in-stream mechanical aeration at Paerdegat Basin was not further developed.

In-Stream Natural Aeration

An in-stream natural aeration system is a relatively simple system utilizing coarse bubble technology. Airflow to the basin is distributed through a series of perforated hoses and/or pipes located on the basin bottom, and attached to a shore-side air supply system. Aeration is accomplished without the use of diffusers and is employed generally for mixing stratified water bodies. During the mixing process, bottom layers having low DO levels are brought to the surface and mixed with higher DO waters. At the surface, reaeration occurs by direct transfer from the atmosphere. Bubbles rising through the water column also transfer oxygen to the water body, as well as aid in transporting the low DO water layer to the surface. Oxygen transfer in this manner is more efficient however, in water bodies with greater depth.

In-stream natural aeration systems have been used primarily in lakes and water supply reservoirs for mixing purposes. Because these systems are designed primarily for mixing, they tend to be of smaller capacities. Additionally, aeration is primarily accomplished by vertical mixing actions in a stratified water body. Direct diffusion of air is a secondary transfer mechanism in this application, and is typically more effective at greater depths. Paerdegat Basin is considered a shallow water body without much stratification, and is therefore not a good candidate for natural aeration technology.

In-Stream Forced Air Diffusion

An in-stream forced air diffusion system would consist of equipment typically located on the bottom of the water body, designed to diffuse air up through the water column thereby accomplishing oxygen transfer. The complete diffused air system would consist of porous or non-porous submerged diffusers, headers, air mains, and the blower and appurtenances through which the air passes.

While the most common materials of construction for the diffuser is ceramic, many types of materials have been utilized. Porous diffusers also come in many types, such as plates, tubes, domes and discs. Plates, domes and disc diffusers are normally installed in a total floor configuration, but they also have been placed along the perimeter of tanks or basins to generate a single or double roll pattern. Disc and domes are normally arranged in a grid pattern with variable spacing. Generally, full floor coverage is the most efficient diffused aeration configuration.

Non-porous diffusers are available in a wide variety of shapes and materials and have larger orifices than porous devices. Non-porous diffusers can vary from simple holes drilled in piping to specially designed openings in metal or plastic devices. Typical system layouts for non-porous diffusers are similar to those of porous diffuser systems.

Oxygen transfer to the water column is much greater with a decrease in the bubble size. Therefore, fine bubble diffusers generally have the highest oxygen transfer efficiency. There are times when actual field and/or process conditions preclude the use of fine bubble technology, and medium and coarse bubble diffusers are used. While fine-bubble diffusers are more efficient at the transfer of oxygen to water, they could potentially prove problematic (i.e. clogging) in Paerdegat Basin due to the solids and sediment in the basin. Therefore, coarse bubble technology was considered for this particular technology, and all other technologies that were subsequently analyzed.

Side-Stream Forced Air Diffusion

A side-stream forced air system would require construction of a side-stream aeration tank adjacent to Paerdegat Basin. Under this scenario, porous or non-porous diffusers would be utilized to transfer oxygen into the water column.

A side-stream aeration tank would be constructed of reinforced concrete and could be either open to the atmosphere, or covered to control potential volatile organic compounds (VOC) emissions. Air would be transferred to the flow within the side-stream aeration tank via porous and/or non-porous diffusers. The actual choice of diffuser would impact the side-stream aeration tank's configuration and geometry.

Implementation of this type of aeration system would also require construction of an inlet pumping station consisting of instrumentation and mechanical controls, influent channels, mechanical bar screens and screening handling/disposal, isolation gates, and distribution channels to the aeration tanks. The air supply system would consist of centrifugal blowers housed in a blower building, air discharge manifolds, and air supply piping, all located adjacent to the aeration tank.

The advantages of using a side-stream forced air diffusion system for Paerdegat Basin is that it is a proven efficient means of supplying and transferring oxygen to a liquid. The entire system would be land-based making maintenance and operation easier over previously discussed in-stream systems.

Disadvantages of the side-stream forced air diffusion system is that it would require extensive structures be built along the basin, and also requires both pumping and air supply systems be operated and maintained. It will also require an outfall to distribute the aerated flow back to the head of the basin.

Side-Stream Cascade Aeration

A side-stream cascade aeration system would consist of pumping water from Paerdegat Basin to a series of elevated on-shore shallow pools that are linked by cascades. Discharge of aerated flows would also be through an outfall structure/piping back to the basin.

The on-shore pools would be constructed at an elevation that would allow water from the first pool to flow into a series of progressively lower pools, eventually discharging back to the basin. The pools would be relatively shallow and constructed of reinforced concrete, with flow discharging from each pool via a series of weirs. Aeration would occur as a result of the free fall over the weirs and the resulting turbulence of flow in the next pool. A rough spillway surface could also be designed to further enhance the aeration rate.

Either screw or centrifugal pumps would be used to pump the water to the cascade pools. Screw pumps have an added advantage in that the design of the open screw also allows simultaneous aeration of the flow during transport. An intake structure is required and would be constructed of reinforced concrete. The facility would also include a bar screen, screenings handling and disposal, a series of isolation gates, and distribution piping to the cascades. The pump station would include multiple units to pump the range of flows as process conditions dictate.

As discussed above, use of any of the side-stream alternatives will require the use of an outfall system to return the aerated flows to the basin. The discharge could be from a single point or through a manifold system to provide effective mixing.

Side-Stream Aeration Utilizing Pure Oxygen/Ozonation

A pure oxygen system is complex both mechanically and operationally requiring a specially trained operations staff. A backup liquid oxygen facility would require liquid oxygen supplies be periodically trucked onto the site. A pure oxygen system is also a highly energy-intensive system.

Ozone is also a strong oxidizer and therefore, is very corrosive. Special consideration must be given to all components and tanks used in an ozone system.

In light of these issues, a side-stream aeration system utilizing forced pure oxygen or ozone generation is not recommended for usage at Paerdegat Basin.

Aeration System Design Conditions

The selection of a supplemental aeration technology for Paerdegat Basin was dependent on many varied factors. These factors include the quantity of aeration required, technical characteristics of aeration equipment and the physical and environmental parameters of Paerdegat Basin.

During this evaluation, a range of CSO retention volumes (combined volumes of both in-line and off-line storage) were evaluated in conjunction with aeration. It was found that to reasonably improve the DO levels throughout Paerdegat Basin, a CSO volume reduction of 10 MG (for a total in-line and off-line combined sewer storage of 40 MG) coupled with the addition of 20,000 lbs/day of oxygen (O_2) was necessary. Assuming that water entering the basin is at 90 percent (%) of saturation, or 6.3 mg/L (temperature dependant), each technology was sized appropriately to deliver the required 20,000 lbs/day of O_2.

Water Quality Modeling

An existing three-dimensional water quality model originally developed for Paerdegat Basin was modified to provide a finer spatial modeling grid at the headwaters of the basin, while also allowing evaluation of the impacts of distributing aerated flows to the basin. The original receiving water quality model utilized during preliminary design of the Paerdegat Basin facility was developed using a six-layer model adapted for existing conditions found in the basin. The original model considered the basin in segments spanning the entire width of the basin extending from the bulkhead located at the farthest upstream reach, out into Jamaica Bay. Each segment averaged approximately 500 feet in length towards the head end, becoming larger as it approached Jamaica Bay. The model also included CSO loading and the interaction between the water column and the underlying basin sediments.

The original model was re-developed to include a finer-grid layout at the head end of the basin. The first 1200 feet of the waterway was subdivided into 100-by 100-foot boxes, with 10 layers in the vertical plane. These modifications allowed detailed evaluation of the receiving waters throughout the head end of Paerdegat Basin, and provided insight into the most cost-effective aeration distribution layout.

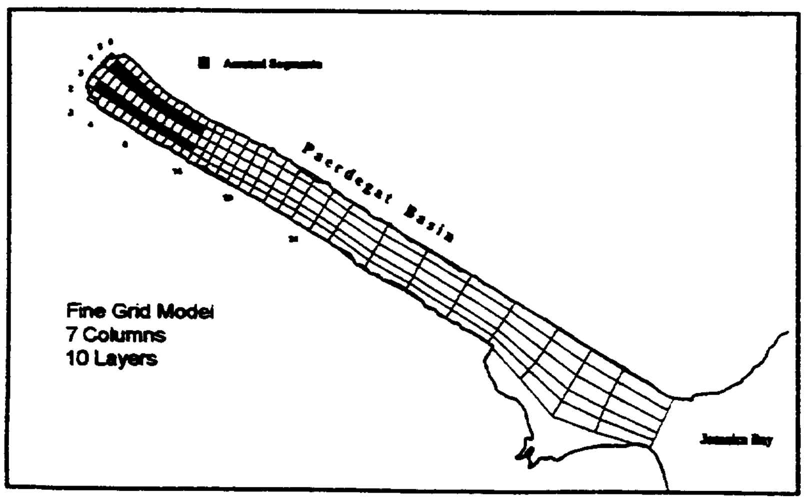

Figure 2 - In-Stream Aeration Model Configuration

Improvements to the DO levels were modeled for changing aeration configurations (both in-stream and side-stream) within the basin. Refinement of the model in this way allowed detailed analysis of aeration impacts on the water quality in distinct model segments of the receiving waters of the basin.

Various configurations were developed for evaluation of aeration layouts during the modeling process. Initial runs for the in-stream alternative included aeration of the entire head-end of the basin from shore to shore, and from the existing bulkhead to roughly 1,150 feet out (maintaining the aeration grid approximately 100 feet from the shoreline). A second alternative aerated two (2) strips 100 feet wide, again from the bulkhead at the head end, to 1,150 feet down the length of the basin. The final configuration maintained the two (2), 100 foot wide rows of aeration out to 1,150 feet from the bulkhead, but maintained a 100 foot distance off the bulkhead (see Figure 2). Modeling showed that sufficient mixing and aeration was obtained in this configuration while minimizing the number of diffusers required.

While the in-stream aeration problem centered on an economical location of the aeration grid within the basin, the concern with side-stream aeration proved to be where the basin water was withdrawn, and ultimately, where it was replaced. Several different configurations were examined including withdrawal at the side of the basin nearest the aeration facility, and replacement back to the headwaters where the DO deficit is the greatest. Numerous scenarios were examined in which the aerated water was pumped back to the head end in different locations. Ultimately, it was determined that to reasonably maintain acceptable DO, it was necessary to return the flow through outfalls and diffusers to three (3) model segments located just off the bulkhead (see Figure 3).

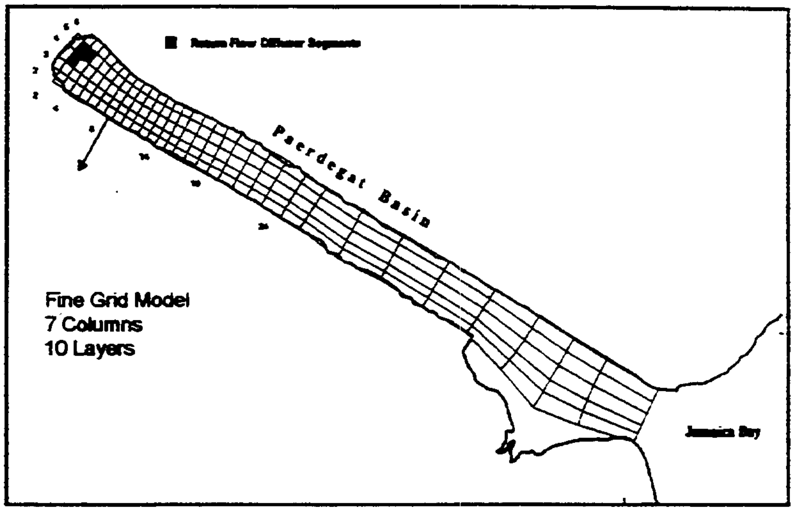

Figure 3 - Side-Stream Aeration Model Configuration

RESULTS

Evaluation of each of the aeration alternatives described above resulted in the selection of three (3) technologies for further development. Specifically, in-stream forced air diffusion, side-stream forced air diffusion, and side-stream cascade aeration. Each of these three (3) technologies was further designed based on several design criteria developed for the project. As mentioned previously, the NYSDEC water quality standard for Paerdegat Basin is never less than 4.0 mg/L. Further consideration was given to interim Long Island Sound Study standards of never less than 2.0 mg/L. In order to reasonably improve DO conditions in Paerdegat Basin with these goals in mind, a range of CSO retention volumes (combined volumes of in-line and off-line storage) were evaluated in conjunction with aeration. The combination of

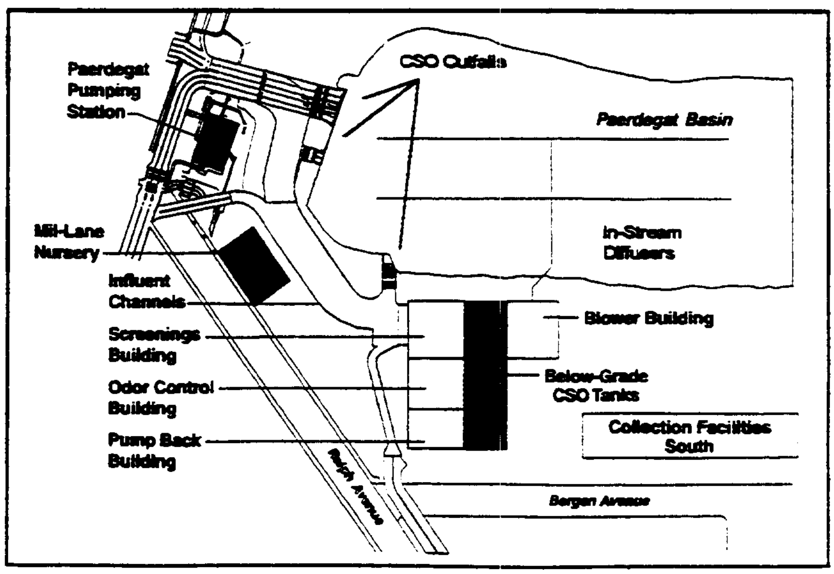

Figure 4 - In-Stream Aeration Site Plan

CSO volume reduction to 40MG with the addition of 20,000 lbs/day of oxygen (O_2) would be necessary to produce desired results in the basin. Each of the following technologies were further designed to supply the required amount of oxygen to the water body as discussed below.

In-Stream Forced Air Diffusion

Designing a coarse bubble aeration system to deliver 20,000 lbs/day of O_2 was the process criteria used to size the blowers, manifolds, headers, air distribution piping, and ultimately the diffusers. It was found that using four (4), 300 Hp centrifugal blowers during operation would be sufficient to deliver 29,400 standard cubic feet per minute (scfm) through 1,470 stainless steel coarse bubble tube diffusers, each with a capacity of 20 scfm, and located at the basin's bottom. The conceptual layout of the diffusers in the basin is shown in Figure 4.

Life cycle costs assumed the projects' useful life to be 20 years, with a yearly inflation rate of 3.4%. It was also assumed that some of the costs such as the availability of power, dewatering, geotechnical considerations, and dredging were already included in the cost of construction of the CSO retention facility.

Capital costs associated with the in-stream forced air diffusion technology were in the range of $11.8M, while operation and maintenance (O&M) costs were $0.67M. The resulting present worth cost was approximately $16.9M (see Figure 6).

Side-Stream Forced Air Diffusion

Design of the side-stream aeration tanks (see Figure 5) allowed the use of reduced process airflow rates compared to the in-stream option. This was in part due to the fact that the sidewall depth of the tank was now controllable. The average depth of Paerdegat Basin after construction of the CSO retention facility and final dredging would be roughly 12 feet at mean tide. The depth of the side-stream aeration tank was set at 20 feet to allow more efficient transfer of O_2 to the water column. Therefore, the required blower capacity was reduced considerably, requiring only 17,000 scfm capacity rather than 29,400 scfm. The resulting number of coarse bubble tube diffusers was also reduced to 850, again each having a capacity of 20 scfm and mounted at the bottom of the tanks. Process air requirements dictated that five (5) blowers, each 200 Hp, be capable of delivering 17,000 scfm of air to the tanks.

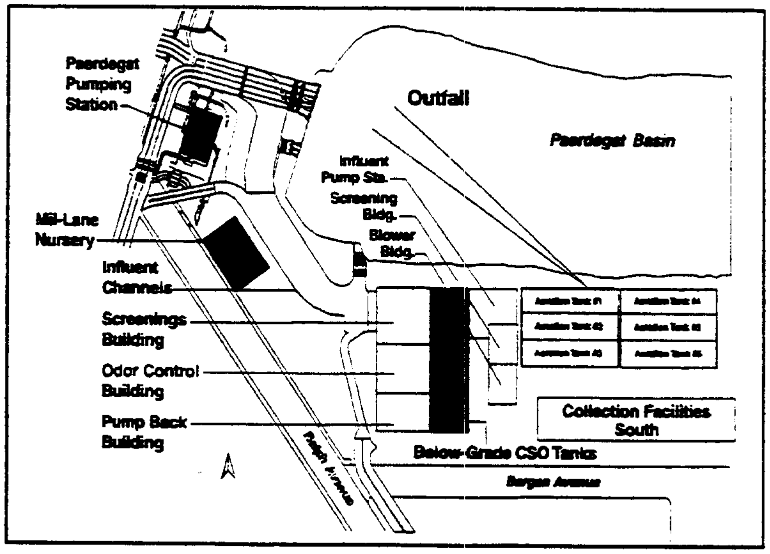

Figure 5 - Side-Stream Aeration Site Plan

Cost Comparison

	In-Stream Forced Air Diffusion	Side-Stream Forced Air Diffusion	Side-Stream Aeration Utilizing Cascades
◆ Capital Cost	$11,880,000	$38,730,00	$24,550,000
◆ O & M Cost	$667,000	$1,480,000	$1,170,000
◆ PRESENT WORTH OF CAPITAL & O & M	$16,900,00	$48,144,000	$32,950,000

Figure 6 – Aeration Technology Cost Comparison

A flow rate of 430 MGD, and hydraulic detention time of approximately 30 minutes, required that 4 aeration tanks be constructed, each measuring 200 feet by 50 feet by 20 feet deep. Pumping requirements of 430 MGD were met with four (4) pumps each with a capacity of 110 MGD. The aerated flows would be returned to the basin through 2-10 foot diameter submerged outfalls.

Capital costs associated with the side-stream forced air diffusion technology were in the range of $38.7M, while operation and maintenance (O&M) costs were $1.5M. The resulting present worth cost was approximately $48.1M (see Figure 6).

Side-Stream Cascade Aeration

Similar to the side-stream forced air diffusion alternative, the cascade system (see Figure 7) would also be required to pump 430 MGD from the basin to the cascades. Six (6) open screw pumps were chosen that were 40 feet in length, set at a 30-degree angle to horizontal, roughly 8 to 10 feet in diameter, and powered by a 420 HP electric motor mounted at the top of each screw. The cascades were designed to drop the flow over 18 feet, and required a weir length of 235 feet. This alternative would also require the construction of 2-10 foot diameter submerged outfalls to return the flow to the basin.

Capital costs associated with the side-stream cascade technology were $24.5M, while operation and maintenance (O&M) costs were $1.2M. The resulting present worth cost was approximately $32.9M (see Figure 6).

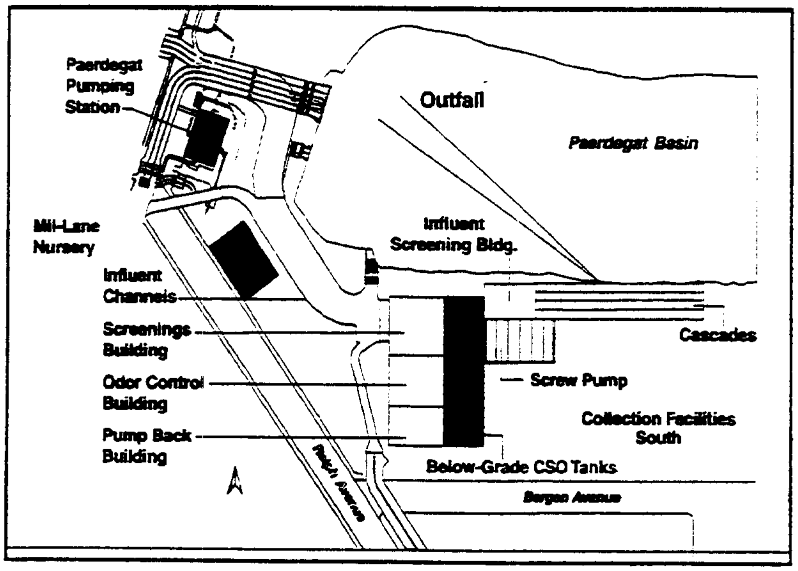

Figure 7 – Side Stream Cascade Aeration Site Plan

Discussion

While all three (3) of the aeration technologies for which additional design was evaluated have demonstrated their ability to improve low DO conditions existing in Paerdegat Basin during the summer months, each has distinct advantages and disadvantages.

Specifically, while the in-stream forced air alternative was demonstrated to be the least costly, the issues of permanent construction and continued maintenance within the waterway remains a disadvantage. In-basin maintenance would require either removal of the affected component, or the use of dive teams to locate and correct any problems. Other operational concerns center on the ability to keep the diffusers clean throughout the year. Expected increases in solids loading to the basin as a result of a reduced capacity CSO facility increases concerns of siltation and subsequent clogging of the diffusers. It is expected that the in-stream system will be operated during the off-season at a reduced air flow rate to lessen the impacts of clogging. However, the added expenses and continuous maintenance required throughout the year is another consideration.

Side-stream forced air diffusion lends to an easier air distribution system and diffuser network to both operate and maintain. All the equipment required for the operation is located on-shore, and as with aeration tanks located at WPCPs, an aeration tank can simply be taken off-line periodically for routine maintenance of the equipment. Another concern of relative significance is the cost of operation of the facility. Not only are there the operational costs associated with the aeration system, but there is the additional cost of pumping flow rates in excess of 400 MGD.

Side-stream cascade aeration appears to be the simplest system to both operate and maintain. Essentially, the only equipment requiring maintenance would be pumping and screening equipment. One drawback however, remains the extensive shore-side construction required.

A common disadvantage to both the side-stream alternatives involves the construction of a large outfall pipe to return the aerated flows back to Paerdegat Basin. Water quality modeling showed that the greatest positive impact on the waterway would be to return the aerated flows towards the head end of the basin. Return of these flows would require the construction of a large outfall structure capable of conveying the flows mentioned.

VOC generation is another concern common to all three (3) alternative technologies. However, the side-stream alternatives lend themselves to a solution. The side-stream tanks, at a significant addition to the construction cost, could be covered and the off-gases collected in some form of emission control system. VOCs generated by the in-stream aeration alternative cannot be readily contained, and remains as a disadvantage that would require further investigation.

CONCLUSIONS

Three (3) aeration technologies were further developed as having the potential to sufficiently raise the levels of DO in Paerdegat Basin throughout the summer months. Specifically, in-stream diffused air employing blowers and an air distribution network on the basin's bottom, and two (2) side stream alternatives were evaluated. One side-stream alternative relied on pumping equipment to bring the waters of Paerdegat Basin to an on-shore aeration tank, where aeration is accomplished using air distribution piping and coarse bubble diffusers. The second on-shore alternative utilized screw pumps to move water from Paerdegat Basin into a series of cascades designed to physically aerate the flow. Both side-stream alternatives would require construction of large outfall pipes to deliver the aerated flows back to Paerdegat Basin in model segments where it was shown through water quality modeling to be the most beneficial.

The exclusive use of any of the in-stream or side-stream technologies discussed above as a CSO treatment alternative would not, by themselves, meet all water quality goals in this CSO basin. The use of aeration as a supplement to conventional CSO controls (i.e. maximized use of existing facilities, retention tanks, etc.) could be used to address DO concerns. However, the continued discharge of solids during wet weather events would result in an increased oxygen demand by the sediments within the basin and must be carefully considered. Further information is required regarding the long-range impacts of a reduction in CSO storage volume and the resulting additional loading of solids, coliforms, and BOD to the basin. The combined use of CSO volume capture and supplemental aeration could provide the needed improvements to water quality in Paerdegat Basin.

All three (3) alternatives have been presented to the NYCDEP recently, and remain under final review and evaluation. Each of the alternatives for aeration of Paerdegat Basin waters will be retained and further analyzed in conjunction with resizing of the CSO retention facility. Remaining issues to be analyzed are as follows:

1. Hydraulic analysis of reduced capacity CSO retention facility;
2. Interaction of aeration system with downsized CSO retention facility;
3. Impact of increased solids/siltation on in-stream aeration equipment;
4. Potential VOC generation and impacts;
5. Permitting and construction issues.

ACKNOWLEDGEMENT

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URBAN RUNOFF FILTRATION FOR CRITICAL SOURCE AREAS

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ABSTRACT

Filtration is attractive in the treatment of stormwater runoff because filters will work on intermittent flows without significant loss of filtering capability. They also do not require a large surface area, and can easily be retrofitted in urban areas at the base of a watershed or problem point source area where land is expensive. Several types of media, peat moss, activated carbon, zeolite, sand, composted leaves, and an agrofiber have been used successfully or have been proposed for use in stormwater runoff filters in the United States. Experiments have been run during the past three years to test the usefulness of each medium as a stormwater filter under 'typical' loading rates, to determine the chemical breakthrough of each medium when in solution with other competing ions, and to analyze the effect of non-normal pHs and ionic strengths on the sorption ability of each medium. Each of these media was combined with sand in a 50/50 mixture by volume in order to control the hydraulic flow rate through each column.

Results of the field testing under 'typical' conditions showed that the activated carbon, peat moss, zeolite and compost were the most efficient at removing toxicants (including organics and metals) from the runoff and retaining them during subsequent flushings with clean distilled water. Sand, the most common filtering medium, was found to effectively remove toxicants from the runoff; however, analysis of the effluent from subsequent flushings of the sand with clean water indicated that the toxicants were being displaced from the pores where they were "trapped" by the water, resulting in effluents that were more toxic than the influents. Additions of color-causing compounds occurred in both the compost and peat media. Both a high ionic strength influent (conductivity > 1000 µS/cm) and a high pH influent (pH > 9) were shown to interfere with sorption of many pollutants for all media examined. Pollutant removals were poorest when the pH and ionic strength were both high, although each could affect pollutant removal independently.

Breakthrough tests at extreme conditions of low pH show that these media are capable of removing greater than 80% of the influent copper until the cumulative copper loading on the media exceeds 0.1 – 0.4 mg Cu/g media for the zeolite, agrofiber, and activated carbon and 1-1.5 mg Cu/g media for the peat moss and compost. Tests done under more normal conditions (influent pH 6.5-7) showed that copper removals exceeded those at low pH conditions. Eighty percent removal is expected for these media at neutral pH until the cumulative copper loading exceeds 0.35 mg Cu/g media for the activated carbon and zeolite and greater than 1-2 mg Cu/g media for the peat moss, compost, agrofiber, and a cotton textile plant waste. For phosphate, greater than 80% removal of phosphate from a low pH influent was possible until the cumulative loading exceeded 0.1 – 0.4 mg PO_4/g media for the compost, peat moss, and zeolite, and exceeded 1.2 mg PO_4/g media for the activated carbon and agrofiber. When the influent pH was neutral, the cumulative loadings for 80% removal were significantly poorer than they were for the low pH conditions, approximately 10% of those found for the low pH conditions.

Data from these laboratory tests has been used to prepare design guidelines for stormwater filters. If the runoff is not being pretreated by settling, then the suspended solids loading on the media will be the controlling design factor. The filters will clog long before their chemical removal capacity is approached. However, if the runoff is pretreated by sedimentation, then the chemical capacities of each media for the pollutant(s) of interest will control the quality of the effluent and the life of the filter. Example design calculations are given in the discussion section of this paper.

KEYWORDS

Urban runoff, filtration, sorption, activated carbon, peat moss, zeolite, compost, filter design

INTRODUCTION

Two popular methods of disposing of urban stormwater runoff are discharging it to a surface water or infiltrating it at designated locations to replenish the groundwater. Due to urbanization, many natural infiltration areas have disappeared permanently, due to both covering the land with roads and buildings and to the regrading and compacting that accompanies construction. Along with the decrease in area available for infiltration, the volume of runoff from urban areas has increased, as has the runoff's pollutant loadings. The need for 'relatively clean' stormwater runoff for either surface water discharge or infiltration has led to the investigation of cost-effective treatment techniques, especially for areas where the pollutant loadings are expected to be greater than normal. The rationale for treating runoff at its source comes from the knowledge that stormwater runoff from many areas is not badly polluted and is suitable for discharge or infiltration. It is just the runoff from certain problem locations, "critical source areas," that cause the receiving water or groundwater problems, and it is cost-effective to treat these smaller volumes of water before they contaminate the larger volume of runoff in a municipal storm sewer system. Examples of these 'critical source areas' where higher than normal pollutant loadings can be expected include the following: airport deicing facilities, auto recyclers/junkyards, commercial nurseries, parking lots, vehicle fueling and maintenance stations, bus or truck (fleet) storage areas, industrial rooftops, marinas, outdoor transfer facilities, public works storage areas, and vehicle and equipment washing/steam cleaning facilities (Clark, 1996).

Urban runoff is comprised of many different flow phases. These may include dry-weather base flows, stormwater runoff, combined sewer overflows (CSOs) and snowmelt. The relative magnitude of these discharges varies considerably, based on a number of factors, especially season (cold versus warm weather or dry versus wet weather) and land use. Land development increases stormwater runoff volumes and pollutant concentrations. Impervious surfaces, such as rooftops, driveways, and roads, reduce infiltration of rainfall and runoff into the ground and degrade runoff quality. Generally, the 5-day biochemical oxygen demand (BOD_5) and nutrient concentrations in stormwater are lower than in raw sanitary wastewater; they are closer in quality to treated sanitary wastewaters. However, urban stormwater has relatively high concentrations of bacteria, as well as high concentrations of many metallic and some organic toxicants. A brief summary of stormwater runoff quality is given in Table 1.

Single, small point-source treatment devices have been developed and are currently being marketed. Most of these treatment devices, however, are designed to remove settleable solids, not colloidal or soluble pollutants. Only recently are these in-line treatment devices beginning to use filtration as a planned treatment step to remove the colloidal and soluble pollutants. Filtration removes pollutants from the solution by attaching them either to the media itself or to previously attached particles. Filters with an adsorption/ion exchange capability will retain pollutants that were removed during prior storms and not allow them to be flushed out of the filter. The performance of these filters is measured not only by the traditional filter parameters (surface area, depth and profile) but also by percentage of removal of the pollutants of interest from the influent. Stormwater filters currently in operation typically use sand, leaf compost, or peat. The purpose of this project is to determine the design parameters for stormwater filters based upon both the physical and chemical capacities of the different media.

Sand

Sand filtration is common throughout the United States, especially in water and wastewater treatment plants. Slow-sand filters are characterized by low filtration rates, an extremely narrow range of particle sizes (low uniformity coefficient, between 2 and 5), the lack of chemical pretreatment, relatively long filter runs between cleanings and surface scraping and sand removal instead of backwashing. Slow sand filters are extremely effective in removing suspended particles (effluent turbidities below 1.0 NTU), bacteria, viruses and Giardia cysts. Sand filters in Austin, Texas, used both for single sites and for drainage areas less than fifty acres, are designed to hold and treat the first one-half inch of runoff with very good pollutant removal ability. Sand filters in the Washington, D.C. area are designed to retain and treat three-tenths to one-half inch of runoff, depending upon the impervious surface amount in the drainage area. The Delaware sand filter should remove 75 – 85% of the influent suspended solids but with minimal to no removal of soluble compounds (Clark, 1996).

Table 1. **Stormwater Runoff Quality (concentrations in mg/L)**

Location	Land use	Susp. Solid	COD	Total P	Copper	Lead	Zinc	Ref.
Toronto, Ontario	Residential (median values)	22	55	0.28	0.03	0.06	0.06	1
Toronto, Ontario	Industrial (median values)	117	106	0.75	0.06	0.08	0.19	1
Bayreuth, Germany	Urban roof & street (range)	4-296	N/A	N/A	0.01-0.11	0.005 -0.14	0.07-1.17	2
Topeka, Kansas	Resident/commercial (median values)	362	46	0.36	0.02	0.07	0.11	3
Topeka, Kansas	Agriculture (median values)	671	40	0.79	0.02	0.02	0.06	3
Milwaukee, Wisconsin	Residential (mean values)	N/A	38	0.26	N/A	0.12	N/A	4
Milwaukee, Wisconsin	Commercial (mean values)	N/A	81	0.28	N/A	0.52	N/A	4
Boulder, Colorado	Resident/commercial (range)	24- 3730	9-1557	0.2-7	N/A	N/A	N/A	5

Ref. 1. Pitt and McLean, 1986.
Ref. 2. Daub, *et al.* 1994.
Ref. 3. Pope and Bevans, 1984.
Ref. 4. Novotny, 1986.
Ref. 5. Bennett, *et al.* 1981.

Activated Carbon

Activated carbon has been used for more than fifty years in the drinking water treatment industry to remove taste- and odor-causing compounds, along with most synthetic organic chemicals, pesticides, herbicides, color and trihalomethane precursors. Slow granular activated carbon filters achieve excellent (> 90%) organic removals, with the removal efficiency being limited by the depth of the filter due to 'slowness' of the transport kinetic and attachment mechanisms inherent in activated carbon sorption. Aged activated carbon filters, i.e., those with a growing microbial community are especially effective at treating wastewaters with toxic or inhibitory organic chemicals in it. Iodine and iodide compounds, chlorite, phenols, hexavalent chromium and mercury have been successfully removed by activated carbon (either granular, powdered, or imbedded in a synthetic fiber) (Clark 1996).

Peat

Peat filters can extract substantial amounts of either free-phase or dissolved hydrocarbons from water. Peat adsorption generally seems to increase as the degree of decomposition increases. The binding of polycyclic aromatic hydrocarbons (PAHs) appears to be controlled by both adsorption and partitioning with the filter media. Nitro and hydroxyl groups on a sorbate molecule tend to strengthen the molecule's sorption. Peat can easily adsorb polyvalent cations, including transition metals, and polar organics. Substances adsorbed by peat include calcium, copper, lead, zinc, mercury, nickel, iron, manganese and chromium. When filtering unbuffered solutions of metals with peat, the pH will drop between 0.2 and 0.6 pH units because of the release of humic and fulvic acids during adsorption or ion exchange. Another disadvantage of peat as a filter material is that it will leach color and possibly some nutrients upon wetting. Peat-sand filters have been used for stormwater treatment. They are expected to have excellent removal rates for phosphorus BOD, trace metals and pathogens, and with a good grass cover, other nutrients

(Clark, 1996). Multi-Chamber Treatment Trains in Milwaukee, WI (peat-activated carbon-sand filter) and Minoqua, WI (peat-sand filter) in which the filter has been used to 'polish' the settling chamber effluent have shown that the device to remove heavy metals, PAHs, pesticides, and COD (Pitt, *et al.* 1997).

Compost

Composts made from yard waste, primarily leaves, have been found to have a very high capacity for adsorbing heavy metals, oils, greases, nutrients, and organic toxins from the influent water due to their high humic content and large number of sorption sites. The composted leaf filter was developed by W&H Pacific for Washington County (WA), the Unified Sewer Agency and the Metropolitan Service District of Washington County, and is now marketed by Stormwater Management Systems, Inc. (Portland, OR). The filter consists of a bottom impermeable membrane with a drainage layer above it. Above the drainage layer is a geotextile fabric upon which rests the compost material. During testing of the prototype as a treatment for stormwater runoff, turbidity, suspended solids, volatile suspended solids and settleable solids removal was greater than 80%, as was removal of copper, zinc, lead, aluminum, iron, petroleum hydrocarbons and oil and grease. Removal of total solids, COD, total phosphorus, ammonia and total Kjeldahl nitrogen was between 40 – 80% (CSF Systems, 1994).

Zeolite

Zeolites have been used for many years in the chemical process industry as molecular sieves, i.e., they will adsorb a wide range of compounds up to the size limit of their pores. Unlike activated carbon, zeolite pore sizes are more uniform without having macropores, mesopores and micropores. Also, because zeolites are polar, it will have not only van der Waals forces to aid in sorption, but also induced dipole interactions and other electrostatic forces, such as polarization, dipole and quadrupole interactions. Zeolites can adsorb higher molecular weight aromatics, as well as unsaturated hydrocarbons. Modified zeolites can remove chlorinated aliphatics and benzene derivatives, as well as transition metal cations (such as lead, chromium and selenium) (Clark, 1996).

Agrofiber and Cotton Textile Waste

The Forest Products Research Lab agrofiber product was developed as both an economic oil adsorbent and an economic ion-exchange media for pollutant removal from water. Kenaf and jute fibers, along with forest wastes such as barks and pine needles, have been found to remove copper efficiently from water (Forest Products Research Lab, 1995).

The cost of disposing of large quantities of waste cotton thread has led Russell Athletic Corp. (Alexander City, AL) to look for alternative uses for this material, such as its use in stormwater treatment devices. Prior testing of a cotton waste called Enretech (RAM Services, Birmingham, AL) indicated that there was a limited capability for sorption and ion exchange on these cotton wastes with removal capabilities being approximately equal to that of the agrofiber.

METHODOLOGY

The main objective of this research was to monitor a variety of media used to treat stormwater runoff to determine their overall pollutant removal capabilities. The media included those described in the introduction (sand, activated carbon, peat moss, zeolite, compost, agrofiber and cotton textile waste). Generally, a variety of mechanisms, including straining, sorption, and ion-exchange, is responsible for removing pollutants during "filtration." No attempt was made to determine which mechanisms were responsible for removing a particular pollutant.

Filter columns containing the various media were constructed in glass, Kimax-brand, one-liter, graduated burets (ID = 48 mm), giving a cross-sectional area for filtration of 18 cm^2. Filter columns were constructed first by placing a square piece of fiberglass window screen in the bottom of the buret and filling the buret to the 1000 mL line with epoxy-coated fish tank gravel (3-4 cm depth). A 15 cm deep layer of fine sand (sandblast grade from Porter Warner Industries, Birmingham, AL) was added on top of the gravel (fill to

700 mL line) before a 30 cm layer of selected filtration media was put in the column (fill to 100 mL line). The columns were constructed using the recommended depths for the Austin sand filter and preparatory times and steps being those of compost filter system, as supplied by CSF Systems, Inc. All sorption media were mixed with an approximately equal volume of sand in order to maintain a relatively consistent hydraulic conductivity between media. Filter columns were reconstructed between each type of test.

The filter columns were placed on a specially constructed carousel. The water was delivered to a flow splitter using a Masterflex® Peristaltic Pump with Masterflex Tygon® tubing. A funnel-type flow splitter was constructed of Delrin™ plastic. Reinforced Tygon® tubing was used to deliver the water from the flow splitter to the individual columns. Prior to construction of the carousel and splitter, all proposed construction materials were leach-tested by soaking representative pieces in 18 MΩ water for approximately 65 hours. Testing of the leachate water showed that the materials were acceptable, with minimal-to-no adverse contamination expected.

The first tests performed were those which determined the solids removal capacity and solids loading at clogging for these media. The solution used was tap water in which a known quantity of a local clay soil had been suspended (approximately 4 g/L). A constant head of approximately 8 cm of clayey water was maintained on the tope of each column. The flow rate of the effluent was measured for each column at designated intervals until clogging occurred.

The second series of tests (performed on new columns) included evaluating the effects of pH and ionic strength on the pollutant removal capabilities of these media. This work was performed as a 2 x 2 factorial design for pH and ionic strength. The test water was runoff water collected at the storm drain inlet for the UAB Remote Transportation Parking Lot and Fleet Services Maintenance Yard. This location was used because it was expected that the pollutant loadings from this area would be similar to that found at similar locations. pH was adjusted using sulfuric acid (pH 4 – 5) or sodium hydroxide (influent pH 9 – 10). Ionic strength was adjusted using a salt made from evaporated sea water. Influent and effluent samples for each media were analyzed for toxicity, turbidity, conductivity, color, pH, chemical oxygen demand (COD), hardness, suspended solids, particle size distribution, and heavy metals (copper, lead and zinc).

The third series of tests were the breakthrough tests to determine chemical capacity of the media. These tests used a tap water to which specific concentrations of certain stormwater pollutants (reagent grade copper, lead, zinc, phosphate, nitrate, and ammonia) were added. Since the standard solutions were acidic (pH < 4), they used up the buffering capacity of the tap water. Sodium hydroxide was added to the test water for the neutral pH breakthrough tests to raise its pH to 6.5 – 7. Influent and effluent samples were tested for turbidity, conductivity, color, pH, chemical oxygen demand (COD), hardness, and heavy metals (copper, lead and zinc).

The final series of tests included evaluating the filtering ability of the media using pre-settled stormwater runoff. The runoff water was from the UAB Remote Transportation Parking Lot and Fleet Services Maintenance Yard. The samples were analyzed for toxicity, turbidity, conductivity, color, pH, hardness, solids (total, dissolved and suspended), particle size distribution, major cations and anions, semi-volatile organics, pesticides and heavy metals (copper, lead and zinc).

RESULTS

The ability to remove suspended solids also is dependent upon the particle size distribution of the influent, with all media having difficulty removing solids that are less than few microns in diameter. Removal efficiency is generally greater when the influent TSS is higher for two reasons: 1) captured particles help trap other particles by reducing pore sizes; and 2) runoff with a low TSS likely has more particles that are closer in size to the pore size of the media (therefore less likely to be captured). The test observations indicated that only about 2.5 cm of the filter columns (about 10% of the column depth) were actually used for solids retention during these tests. It is assumed that a full-scale filter could use about 5 times these depths for solids retention if careful, selective piping to deeper depths, while preventing short-circuiting of the entire filter, was allowed. Results of the clogging tests are shown in Table 2 for a full-scale filter installation.

TABLE 2. **Removal Efficiency for Suspended Solids for Pre-settled and Unpresettled Influents**

Media	Percent TSS Reduction (Avg. Influent TSS = 10 mg/L)	Percent TSS Reduction (Avg. Influent TSS = 30 to 60 mg/L)
Sand Carbon-Sand	>50%	>90% >90%
Zeolite-Sand Agrofiber, Cotton Waste	20-50%	>90% 80%
Peat-Sand Compost-Sand	<10%	80-90% 80%

The effects of pH and ionic strength were also investigated. It was found that a non-neutral influent pH and ionic strength generally significantly affected the removal capability of the media. In the carbon-sand material, metals removal was dramatically affected by influent pH, with the greatest removal efficiency and best effluent quality occurring when the influent pH was greater than 7. A high ionic strength enhanced the carbon-sand's ability to reduce turbidity but negatively affected its ability to remove toxicity, color and COD. For the peat-sand material, a low influent pH caused a poorer effluent quality in terms of hardness, zinc, copper and color, while a high influent pH caused higher effluent COD concentrations. The effluent turbidity and color were lower for the zeolite-sand material when the influent ionic strength was high, but the effluent hardness was greater. For the metals for the compost-sand medium, the poorest effluent quality occurred when the influent pH was low and the influent salt concentration was high. The addition of salt to the influent also increased the effluent hardness of the compost-sand material. The benefit of the compost is that it always moved the solution pH toward neutral (for both low and high influent pHs).

Chemical capacity of the media was evaluated in a series of breakthrough tests. The results are shown below for copper and phosphate for both the low pH and neutral pH tests (compost not shown for phosphate since no removal occurred). Copper removal improves when the pH is closer to neutral while phosphate removal is best when the influent pH is low. Figures 1 through 4 illustrate the chemical capacity of the media as found during the breakthrough tests.

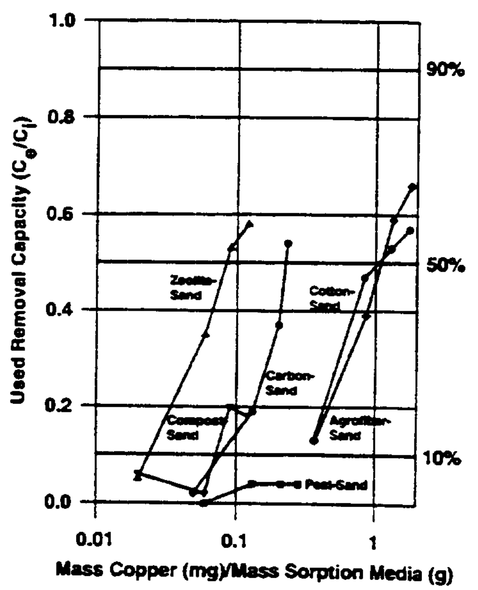

Figure 1. **Copper Breakthrough at Neutral pH (Influent 6.5 – 7)**

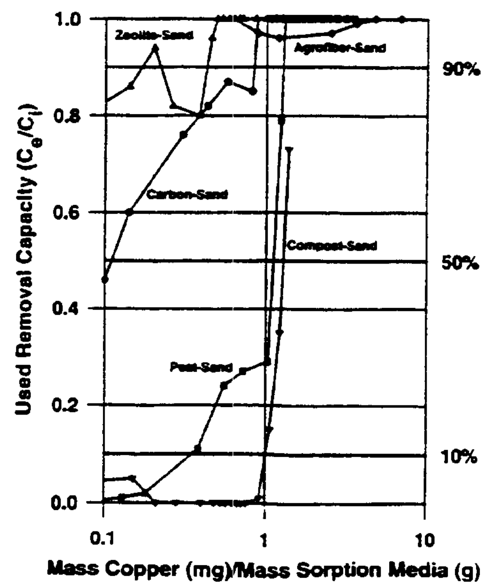

Figure 2. **Copper Breakthrough at Low pH (Influent 3.5 – 4)**

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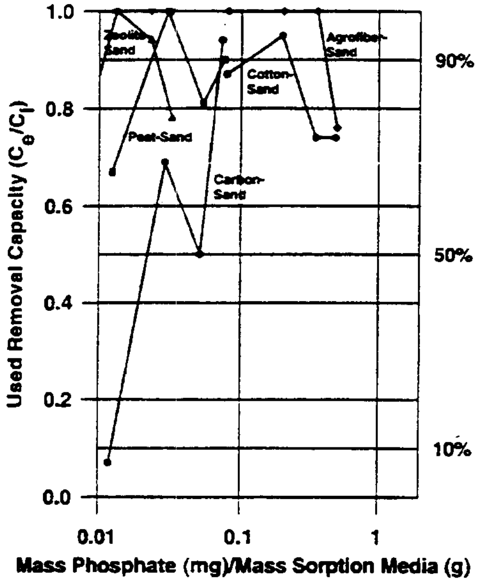

Figure 3. **Phosphate Breakthrough at Neutral pH (Influent 6.5 – 7)**

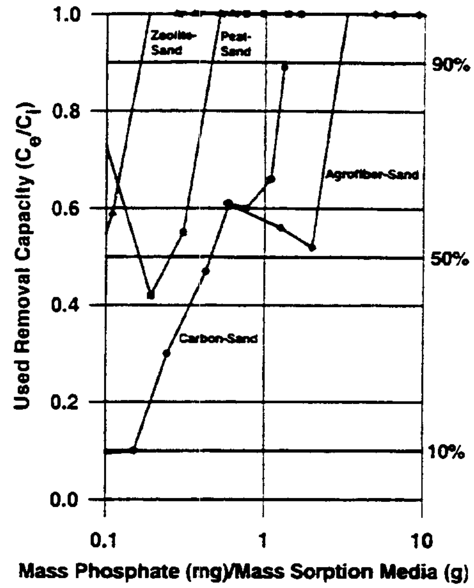

Figure 4. **Phosphate Breakthrough at Low pH (Influent 3.5 – 4)**

Testing with pre-settled stormwater was conducted to evaluate, under typical field conditions, the run times before either clogging or chemical breakthrough occurred. The settling reduced the stormwater suspended solids concentrations to about 10 mg/L, with about 90% of the particles being less than 10 µm in size. The presettling also reduced the other stormwater pollutants (for example, color and turbidity by about 50% and COD by about 90%). This presettling had a significant effect on the media's pollutant removal performance with the results shown in Table 3.

Table 3. **Removal Capability Using PreSettled Influent (Influent TSS = 10 mg/L)**

Media	Additional Comments
Carbon-Sand	Removed toxicity (80%), color (25%), alkalinity (>95%), zinc (50-75%), COD (85-95%), 2,4-dinitrophenol (40%), bis(2-ethylhexyl) phthalate (90%), with minimal effluent degradation
Peat-Sand	Removed toxicity (60%), alkalinity and hardness (50-100%), chloride (<20%), large solids (<50%), zinc (60-70%), 2,4-dinitrophenol (35%), di-n-butylphthalate (65%), bis(2-ethylhexyl) phthalate (20%), dieldrin (70%), while adding color, turbidity, and reducing pH (1-2 units)
Zeolite-Sand	Removed toxicity (>90%), chloride (<10%), potassium (40%), calcium (15%), zinc (60-75%), bis(2-ethylhexyl) phthalate (80%), pentachlorophenol (90%), with minimal effluent degradation
Agrofiber-Sand	Removed zinc (75-80%), pentachlorophenol (90%), with minimal effluent degradation
Sand	Removed volatile solids (<10%), zinc (75-80%), bis(2-ethylhexyl) phthalate (100%), with minimal effluent degradation
Compost-Sand	Removed zinc (75-80%), while adding color to effluent

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DISCUSSION

As can be seen by these results, the characteristics of the influent water should greatly influence the selection of the treatment medium. Generally, most stormwater filters are designed based upon the influent suspended solids concentration and desired suspended solids removal. For most applications, this likely will remain the primary design factor. However, the choice of media likely may be different when the influent suspended solids concentration is low, or when the pH is not near neutral and/or the ionic strength is high. Designers also must remember that most of these media are ion-exchange materials. This means that when ions are removed from solution by the treatment material, other ions are released into the effluent. In most instances, these ions are not a problem in receiving waters, but the designer should know what is added to the water. For this activated carbon, the exchangeable ion was found to be typically sulfate; while for the compost, the exchangeable ion was found to be usually potassium. The zeolite appeared to exchange sodium and some divalent cations (measured as increasing hardness).

Design of Filters for Specified Filtration Durations

The filtration durations measured during these tests can be used to develop preliminary filter designs. It is recommended that allowable suspended solids loadings be used as the primary controlling factor in this design. For these designs, clogging is defined to occur when the water flow rate through the medium becomes less than one meter per day. Filtration, obviously, will still occur when the flow rate becomes less than one meter per day; however, except for small rains in arid areas, much of the runoff would have to bypass the filter and would not be treated. Table 4 summarizes the results of these tests by giving the amount of suspended solids that can be loaded onto a full-scale filter before the capacity is reduced to the flow rates shown. A multiplier of five was used to account for the greater anticipated filter flow capacity associated with full-scale operations.

Table 4. **Filter Categories Based on Capacity as a Function of Suspended Solids Loading**

Capacity to <1 m/day (gSS/m^2)	Capacity to 10 m/day (gSS/m^2)	Filtration media in category
5,000	1,250	Cotton-sand; Agrofiber-sand
5,000	2,500	Compost-sand; Peat-sand
10,000	5,000	Zeolite-sand; Carbon-sand
15,000	7,500	Sand

The wide ranges in filter run times as a function of water loading are mostly dependent on the suspended solids content of the water, especially for the tests where the water was presettled. For this reason, the suspended solids loading capacities (Table 4) are recommended for use when selecting a filter. The most restrictive materials (the cotton textile waste and the agrofiber) are very fibrous and, even when mixed with sand, they still show some compaction. The most granular media (activated carbon and zeolite) are relatively uniform in shape and size but are very large when compared to the sand grains. Sand was used with the carbon and the zeolite to reduce the water's flow rate through the media to increase contact time for better pollutant removal.

One proposed maintenance technique to ensure longer filter run times is the mechanical removal of the clogged layer (top five centimeters). Mechanical removal of the clogged layer to recover filter flow rates was not found to be very satisfactory during this research, but it has been used successfully during full-scale operations. Great care must be taken when removing this layer since loosening the media may enable trapped pollutants (associated with the suspended solids) to be easily flushed from the media.
The above filter capacity ranges are associated with varying test conditions and may be further grouped into the approximate categories shown in Table 4. A multiplier of five was used to account for the greater anticipated filter flow capacity associated with full-scale operations.

Example Filter Designs (Pitt, 1996)

Filter designs can be performed based on the predicted annual discharge of suspended solids to the filtration device and the desired filter replacement interval. As an example, volumetric runoff coefficients (R_v) can be used to approximate the fraction of the annual rainfall that would occur as runoff for various land uses and surface conditions. Table 5 summarizes likely suspended solids concentrations associated with different urban areas and waters.

Table 5. **Suspended Solids Concentration by Land Use**

Source Area	Suspended Solids Concentration (mg/L)
Roof runoff	10
Paved parking, storage, driveway, streets, walk areas	50
Unpaved parking and storage areas	250
Landscaped areas	500
Construction site runoff	10,000
Combined sewer overflows	100
Detention pond water	20
Mixed stormwater	150
Effluent after high level of pretreatment of stormwater	5

Using the information in the above table and the local annual rain depth, it is possible to estimate the annual suspended solids loading from an area and to size a needed stormwater filter. The following three examples illustrate these simple calculations.

Example 1. A 1.0 ha paved parking lot (R_V = 0.85), in an area receiving 1.0 m of rain per year:
(50 mg SS/L) (0.85) (1 m/yr) (1 ha) (10,000 m^2/ha) (1,000 L/m^3) (g/1,000 mg) = 425,000 g SS/yr

Therefore, if a peat/sand filter is to be used having an expected suspended solids capacity of 5,000 g/m^2 before clogging, then 85 m^2 of this filter will be needed for each year of desired operation for this 1.0 ha site. This is about 0.9% of the paved area per year of operation. If this water is pretreated so the effluent has about 5 mg/L suspended solids, then only about 0.2% of the contributing paved area would be needed for the filter. A sand filter would only be about 1/3 of this size but would provide little added benefit if the water was pretreated.

Example 2. A 100 ha medium density residential area (R_V = 0.3), 1.0 m of rain per year:
(150 mg SS/L) (0.3) (1 m/yr) (100ha) (10,000 m^2/ha) (1,000 L/m^3) (g/1,000 mg) = 45,000,000 g SS/-yr

The unit area loading of suspended solids for this residential area (425 kg SS/ha-yr) is about the same as in the previous example (450 kg SS/ha-yr), requiring about the same area dedicated for the filter. The reduced amount of runoff is balanced by the increased suspended solids concentration.

Example 3. A 1.0 ha rooftop in an area (R_V = 0.85) having 1.0 m of rain per year:
(10 mg SS/L) (0.85) (1 m/yr) (1 ha) (10,000 m^2/ha) (1,000 L/m^3) (g/1,000 mg) = 85,000 g SS/yr

The unit area loading of suspended solids from this area (85 kg SS/ha-yr) is much less than for the previous examples and would only require a filter about 0.2% of the roofed drainage area per year of operation.

CONCLUSIONS

Filtration can be a very successful treatment technique for urban stormwater runoff, if the filters are designed and maintained correctly. In general, it is recommended that the filter media be about 50 cm in depth and that a surface grass cover be used (roots should not extend below the top half of the filter). This should enable a filtration life of about five times the basic life observed during these tests. In addition, it is highly recommended that significant pretreatment of the water be used to reduce the suspended solids concentrations to about 10 mg/L before filtration for pollutant removal. This pretreatment can be accomplished using grass filters, wet detention ponds, or other specialized treatment (such as the sedimentation chamber in the multi-chambered treatment train described by Pitt, 1996). The selection of the specific filtration media should be based on the desired pollutant reductions, and the selection should include amendments to plain sand if immediate and permanent pollutant reductions are desired.

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TECHNOLOGY IN THE SEWER BUSINESS

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ABSTRACT: The increasing public awareness of the health hazards associated with wet weather pollution has prompted the Sanitation District No. 1 of northern Kentucky (the District) to develop a sophisticated implementation and response system. The District is utilizing technology to develop strategic plans to meet environmental sewer system regulations and serve its customers. The plans begin with databases and mapping in a Geographical Information System (GIS) for a three county wide area. The District has then taken GIS to the next level, it uses a translator to provide the data from GIS to external applications. The applications include hydraulic sewer and river models which simulate combined sewer overflows and the local rivers. The model results are then used in GIS to illustrate and develop plans to address sewer system issues which included combined sewer overflows and inflow/infiltration. This paper explores the applications which use GIS data to assist the District in project scheduling and management.

INTRODUCTION: In early 1995, the District comprised the trunk and interceptor sewers in northern Kentucky's Campbell and Kenton Counties. Late that year through county and city acquisitions the District grew from 100 miles to more than 1,000 miles of sanitary sewers. The District now serves more than 301,000 people and a facility plan projects that number will be around 392,000 in the year 2017. From development of a Geographic Information System (GIS) to computer modeling to billing implementation, technology investments were viewed as necessary changes to allow the organization to meet the needs of the region into the 21st century.

METHODOLOGY

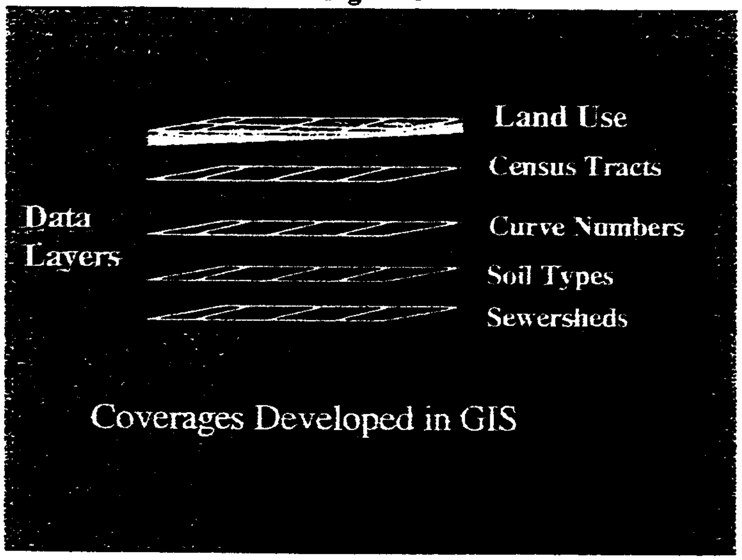
Geographic Information System: In early 1995, all plan and profile information for the sewer system in the newly consolidated district were on paper. An existing third party Arc/Info GIS was used to develop the District's sewer system. With basic attribute data in the GIS, the framework for a Computer Maintenance Management System (CMMS) was developed that included sewer component tables.

Various forms of information can be input into the GIS coverages. These can be defined in Polygons—shapes input to define data in specific areas—which were created to identify different types of statistical, soil, or land use information. The polygons for soil can be used to develop stormwater runoff coefficients. The land use polygons were used to calculate dry weather flows. The statistical landuse polygons were used to develop population projections within certain areas. Through the development of programs within ARC/INFO and FoxPro, this data was indirectly used as input for the sewer system models. The GIS coverages developed or used are shown in **Figure 1**. Satellite technology-based Global Positioning was used to update the mapping for modeling environmentally sensitive structures such as combined sewer overflows.

A coverage containing all the generalized land uses was developed for planning purposes. Polygons were created to separate different land uses throughout the District. The land use database was used to develop dry weather or sanitary flows for use in the model. Soil survey data was collected for the three counties from the National Resources Conservation Service. The soil survey data was categorized into four hydrologic soil groups necessary to perform the runoff analysis. Population census tracts can be unioned with other polygons to determine populations within certain areas. This provides the population densities within certain land uses in a sewershed. Hydrologic soil type, curve type, and curve number polygons can be used to develop wet or rain weather flow. The polygons have their areas and typical land classifications. These values were imported into a translator where they can be queried for each item in a sewershed.

For a logical development of the land uses within the northern Kentucky area, 1995, 2002, 2007, 2012 and

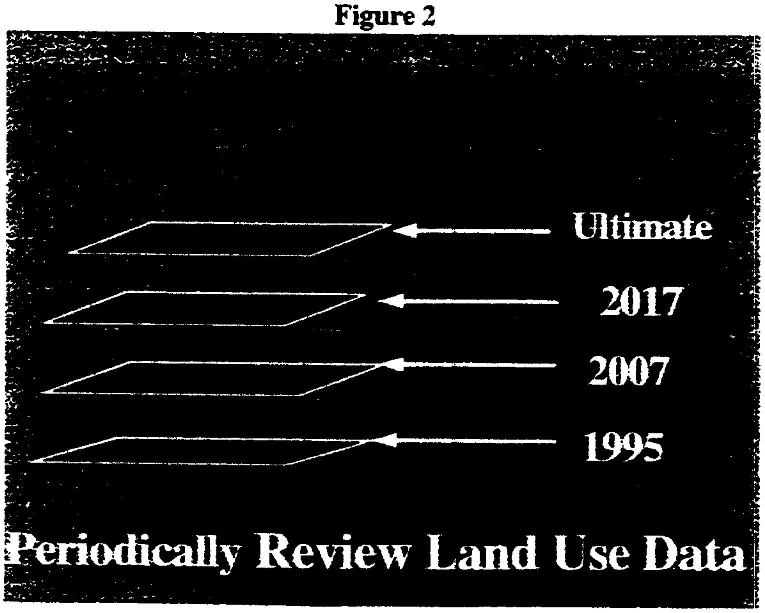
Figure 1



"ultimate" land use polygons were developed. To create the future hydrographs, the respective land use polygons were used. A schematic with the years available in GIS is shown in **Figure 2**. These polygons will permit the District to set up different alternatives on how the system will operate in any of those years.

This complete methodology allows for change in the land use data. Any changes in the land use coverages

Figure 2



in GIS can be updated by creating a new polygon file. The file can then be exported to XMS in FoxPro for a new system analysis.

The 2017 and Ultimate polygons were used to develop the Facilities Plan. **Figures 3** and **4** illustrate how the high density residential area, shown in yellow, is projected to increase by the year 2017.

Figure 3

Figure 4

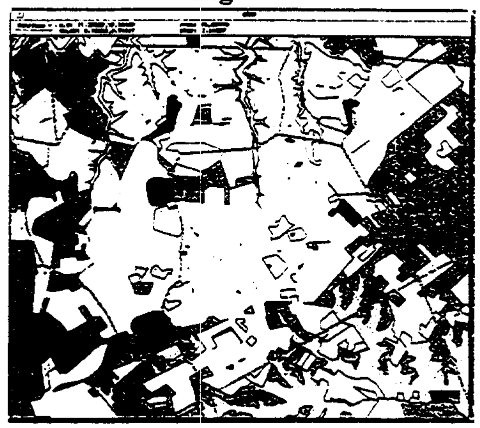
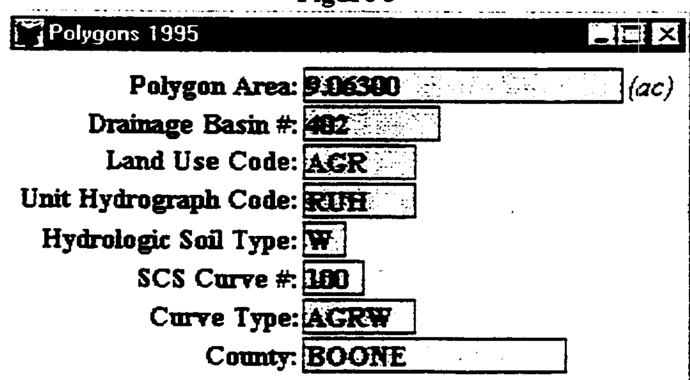


Figure 5 numerically represents the landuse and is available for each polygon in the GIS land use coverage The future land use polygons are estimates of how the area will develop. As actual developments occur, the databases should be updated to represent actual conditions. This complete methodology allows for change in the land use data. In order to generate accurate results the land use data must be periodically revised. Any

Figure 5



changes in the land use coverages in GIS can be updated by creating a new polygon file. The file can then be exported to a FoxPro XMS for a new system analysis.

FoxPro—GIS Translator

With the concurrent tasks of updating the GIS and the startup of a facility plan for the new District, a common database was developed. The purpose of the database was to provide a central location where data could be stored and used for the benefit of all tasks. An XP-SWMM Management System (XMS) was developed within FoxPro which provides the translator between software packages. It provides the user with a database that keeps track of all items entered by a naming setup in the GIS. Using this setup will allow the data in XMS to easily be transferred to the CMMS in Arc/Info, or other software packages. The prime objectives of the District models are to simulate actual field conditions and to provide a tool for modeling alternatives. Using FoxPro, the polygon data can be used to generate values needed to develop both wet and dry weather hydrographs. Through the development of programs within Arc/Info and FoxPro, this data can indirectly be used as input for sewer system models.

The development of the XP-SWMM Management System (XMS) within FoxPro provided the needed link

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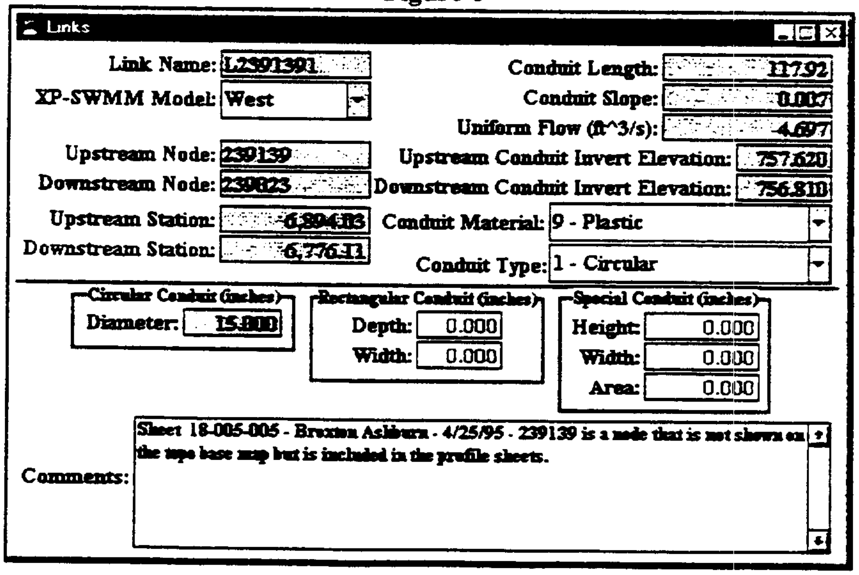
between GIS and XP-SWMM. The purpose of the database was to provide a central location where data could be stored for use in the models. FoxPro, a relational database management tool capable of performing large queries, was identified as the appropriate package for integrating the sewer system data. It is understood that the land use polygons will change over time. This translator between GIS and XP-SWMM was developed to accommodate the changes in GIS. As the coverages are updated in GIS, a database file is created for import into XMS.

RESULTS

Virtual Hydraulic Modeling: The final product is a compilation of team work encompassing databases, GIS and hydraulic models. Each team member played an important role in the creation of dynamic models accurately representing the sewer system and its effects on the environment. Creating a virtual model required the use of several complex modeling packages. The software chosen to model the District sewer system was XP-SWMM. The hydrodynamics of the Ohio and Licking Rivers are being modeled using RMA-2V. WASP5 is being used to develop predictions of bacteria levels in the Ohio and Licking Rivers from XP-SWMM loadings. The results of these three software products, GIS and an IBM Data Explorer resulted in a virtual model of sewage flow from the sewer system into and through the Ohio River. The following sections outline and illustrate how the virtual models at the District were setup and how they are being used.

DISCUSSION

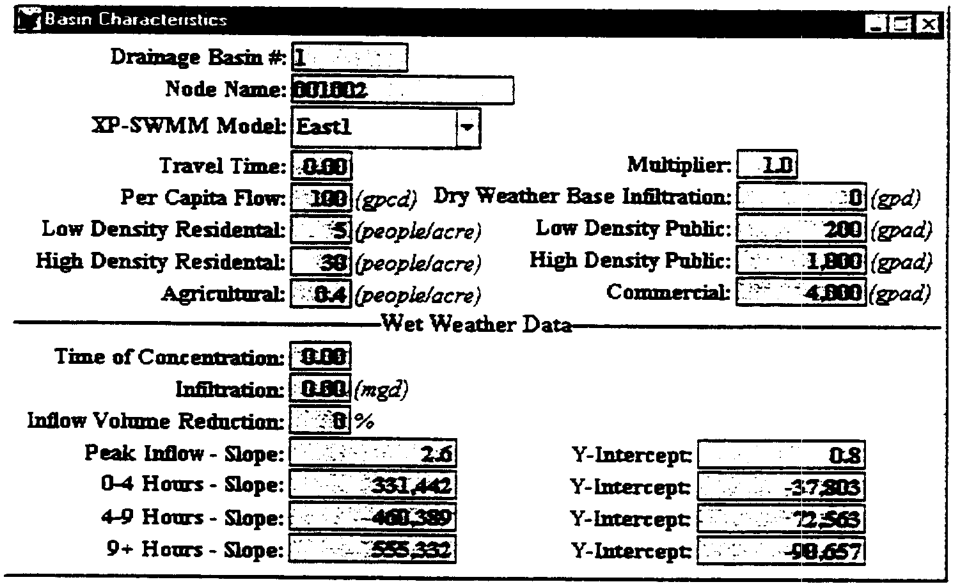
Figure 6



XP-SWMM Model Development: An important factor for choosing a sewer model included its ability to represent both hydraulic and physical field conditions. These models required extensive input requirements to account for the sewer components. Inputting of a single pipe required the opening of several time-consuming windows. Therefore, building the sewer model conventionally would have meant manually inputting physical characteristics for more than 6,280 pipes and manholes. The immense amount of manhole and pipe data to be input into the sewer model required the automation of the task. This was accomplished by developing a program within XMS. The program provided a single input window for each manhole or pipe and formatted the data into a setup that was useful by the sewer model. **Figure 6** is a typical Links input table for pipes. The Links table connects the pipes to their appropriate manholes by name association. The conduit type defines the shape of the pipe. After the shape is defined, the correct sizing menus are highlighted by XMS. Specific model requirements are entered and from that XMS calculates the slope and design flow of the pipe. For model data management the District service area was broken up into six models. Using the "XP-SWMM Model" field, XMS inserts this particular manhole in the correct import file.

Hydrology: The XP-SWMM models require hydrographs in order to simulate actual hydraulic conditions in

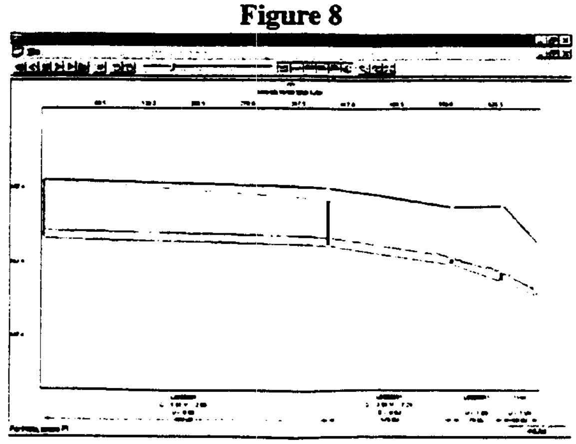
Figure 7



the sewer system. For each sewershed and point source a hydrograph was developed. The fields in **Figure 7** show the type of data entered for each sewershed. The upstream hydrographs were accounted for by inputting them into their actual receiving manholes (Node Name) in the model. Travel times to get to the interceptor sewers were assigned to upstream hydrographs. The creation and manipulation of these hydrographs were performed in XMS. The program in XMS first lags all sewersheds in reference to time zero. Then all sewersheds with the same inflow node are added to make a composite hydrograph. The hydrographs account for flow over a 24-hour period, with inflow at every 15 minutes. These calculations would have been painstaking using regular methods; XMS quickly generates new import files to be used by the sewer model. Using this information dry weather hydrographs were developed for use in the facility plan models. The wet weather hydroghraphs for the combined sewer overflow (CSO) models were developed in XP-SWMM using areas developed in GIS.

To develop dry weather flows, XMS queries for the sum of the different land uses within a sewershed. The land use classifications used include low and high-density residential, agriculture, low and high-density public, open space, and commercial development. Flows from industrial land use are accounted for as point sources. User input based on monitored data define unit hydrographs in XMS to represent land use flows. The unit hydrographs are then multiplied in XMS by areas with the same land use to obtain hydrographs. The separate land use hydrographs produced within a sewershed are then added to make a sewershed hydrograph.

Figure 8



Sewer Modeling: Once input parameters are defined in XMS, hydrographs can be developed for the sewer models. XMS can provide the peak flow and volume of a combined hydrograph for a storm within the monitored range. These hydrographs are then exported into XP-SWMM and checked from monitored data. Hydrographs can be calibrated by adjusting the input variables in XMS.

Figure 8 is a view of a sewer profile in XP-SWMM. Using this model the District can analyze the hydraulic levels in the sewer pipes based on monitored data. The CSO XP-SWMM models provide output used for modeling of the local rivers.

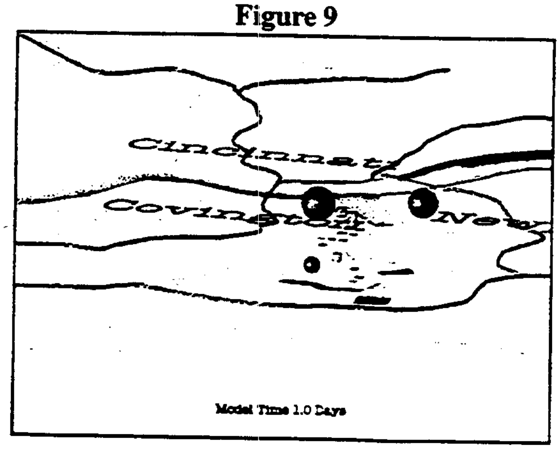
River Modeling: The Banklick Creek water quality model is a one-dimensional finite element model. The hydraulic model, HEC-RAS was used to develop a relationship among velocity and segment depth with flow. This relationship allowed the model to be run dynamically to estimate the stream's response to CSO loadings. Since the CSO flows were estimated to be equal to, or greater than the creek flow, the water mass loadings were included in the overall hydrodynamic modeling of the wet weather events.

The hydraulics and geometry of the Licking/Ohio River system were determined using RMA-2V. This finite difference model conserves momentum to determine the flow conditions based on upstream flow and downstream head. The water quality model of the rivers is two-dimensional. The linkage of the finite difference hydraulic and finite element water quality models presented a unique problem in that RMA-2V only conserves momentum while WASP5 requires conservation of mass. Thus, an algorithm was developed to smooth the flows from RMA-2V and route them through the finite element water quality model.

Water quality: The water quality model WASP5 was employed to estimate the response of Banklick Creek and the Ohio/Licking River system to CSO loads. The WASP5 model simulated fecal coliform loading and a first order die-off term to the system. The dissolved oxygen dynamics consisted of nitrogen kinetics, two types of CBOD decomposition (riverine and CSO), and algal concentrations to scale production/respiration. The model included two CBOD types because the readily available fraction for consumption is different (the "fresher" organics from the CSO discharges are more quickly broken down).

Visualization: The visualization of the system using IBM Data Explorer incorporates all aspects of the efforts. Within one series of images, we have included GIS streams and roads (as a frame of reference), rain gage information (initial frame of reference for runoff), XP-SWMM output (give a frame of reference to load sizes to the streams), Banklick Creek model output (show fecal coliform response of the creek), and Ohio/Licking River model output (includes Banklick Creek and CSO loadings and the response of the rivers).
The inclusion of these data, as shown in **Figure 9**, provide an overall picture of the system that was not available before. By including all five data sources, a more complete cause-effect relationship is presented.

Figure 9



Management Software

The incredible growth of the District required the implementation of a maintenance management system. The growth of the sewer system also meant an increase in customer complaints and maintenance crews. CK System Inc. developed a management system named MaintiMizer. It was implemented to keep track and schedule the daily operations of the District's field crews and operations. Each incident about a structure becomes a permanent record in the MaintiMizer. The history of all maintenance in the system is maintained and any item can quickly be queried in the system. It is used to inventory supplies and to keep track of material as it is installed at different locations. Continuing the planning for the eventual consolidation of all databases in Arc/Info, the naming scheme for the pipe and manholes was maintained. This will allow the data to be imported into the existing databases in Arc/Info by name association. Using this software in conjunction with Arc/Info allows incoming customer complaints to be referenced with pipes and manholes. This software has eliminated large amounts of paper work and improved customer complaint response time.
Telemetering is used to monitor pump stations. All data is sent to a central location where a single person can dispatch crews to a malfunctioning station.

CONCLUSIONS

The District has implemented technology that will take it into the next century. The continued use of databases with the same naming schemes will allow for all data to be centrally located. The eventual goal is to have all databases export their data into Arc/Info. All pipe and manhole changes will be input into the Arc/Info databases. Arc/info will be the central location from where all hydrograph polygon databases and physical model parameters can be exported into XMS. XMS will then develop the input for the sewer model. The use of MaintiMizer moves the District into a scheduled system. Through planning and immediate action these systems have streamlined the time to correct problems in the sewer system. The billing system databases could also eventually be tied into Arc/Info. This would tie customers to certain parts of the sewer system. The continued development of the Arc/Info CMMS will provide the District with a central location for data management as shown in **Figures 10** and **11**. These tables in GIS are being used to inventory the new developments within the District.

Figure 10

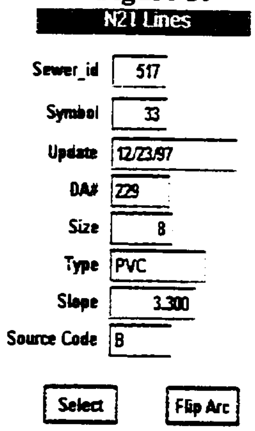
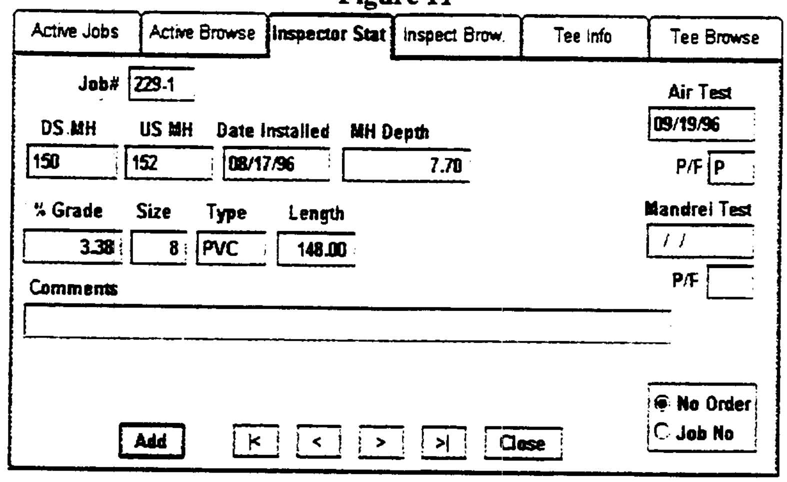


Figure 11



The District is using technology to face its environmental challenges and assists in prioritizing of projects. The results obtained from the modeling and inflow and infiltration studies are being graphically represented in public meetings by using GIS. Using XP-SWMM the user is able to view sewage levels in pipes including bypassing through CSO structures. This information is then fed into RMA-2V and WASP to analyze the hydrodynamics and bacteria concentrations of affected rivers. These additional results are then imported into an IBM Data Explore where the effects of the overflows are seen in a virtual model of the river. Today's technology provides the District with data in ARC/INFO to a dynamic analysis of its sewers operation and effect on the environment. The goal of providing quality services to its customers has taken the District into the 21st century.

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I/I EVALUATION AND REHABILITATION PROGRAM SIMPLIFIED WITH COST-EFFECTIVE GIS IMPLEMENTATION

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ABSTRACT

Many cities and municipalities throughout the United States experience overflows and bypasses from sanitary sewer systems during periods of intense rainfall. With the nation's population becoming more environmentally conscious, environmental regulatory agencies have seen increased pressure to implement more stringent regulations and enforcement policies. Most regulatory agencies encourage and in some cases require cities and municipalities to implement a Sanitary Sewer Evaluation Study (SSES) as a first step to reducing sanitary sewer overflows and bypasses.

Oftentimes, management of data collected during SSES field activities becomes overwhelming and requires automated tracking methods. Data collected during field investigations may include manhole inspection, smoke testing, dyed-water testing, lamping inspections, flow monitoring, CCTV inspections, flow isolation, and building inspections. In addition to SSES field data, historical information, such as maintenance records, reported overflows, and previous rehabilitation, is also evaluated and used as a basis for determining locations of further field investigations.

Once data has been collected, the seemingly insurmountable task of evaluating all the data and developing recommendations for cost-effective inflow and infiltration (I/I) removal and structural rehabilitation must be completed. The data evaluation process can be somewhat simplified with the use of graphical methods to view the data. In an effort to avoid cumbersome paper maps, the industry has developed computerized Geographical Information Systems (GIS) for mapping and graphic data queries. As with many types of new technologies, development of a GIS can be quite time consuming and costly, preventing smaller municipalities from successfully acquiring such tools.

The purpose of this paper is to present the steps followed by Wade & Associates and the City of Fort Worth, Texas in the implementation of a low budget GIS used for successfully evaluating field data and developing recommendations for I/I and structural rehabilitation of the City's Main 390 sanitary sewer collection system. Wade & Associates linked the database developed during field investigations, past maintenance records, and reported overflow records to the City's current AutoCAD® sewer map and orthographic images, using, resulting in a valuable evaluation tool. By using existing computer aided drafting (CAD) maps and providing only information required for sanitary sewer evaluation, costs were kept well within typical non-GIS SSES costs and completed within a short time frame. In addition, due to the time schedule stipulated in the City's Administrative Order, the $20 million rehabilitation effort recommended during the study will require multiple design consultants. The GIS developed during the study will be used to track design efforts of each consultant.

KEYWORDS

Sanitary Sewer Evaluation Study, Geographical Information Systems, Rehabilitation, ArcView®, AutoCAD®, Orthographic

INTRODUCTION

History

The City of Fort Worth operates and maintains an extensive system of wastewater collection facilities. The Main 390 Drainage Area (Study Area) is comprised of approximately 130 kilometers (81 miles) of pipe and is located within the collection system tributary to the Village Creek Treatment Facility. Currently, the entire collection system contains approximately 3,860 kilometers (2,400 miles) of sanitary sewer pipe.

The Main 390 Drainage Area contains primarily residential housing, but also includes some light-industrial, and commercial development. This project is part of the City of Fort Worth's Wastewater Program in response to an Environmental Protection Agency Administrative Order (AO) requiring the City to eliminate sanitary sewer overflows.

Goals Of Study

The City retained the consulting engineering services of Wade & Associates, Inc. in August of 1995 to conduct a flow monitoring program and comprehensive I/I investigation in the Main 390 Drainage Area. Based on the City's past experiences with excessive emergency maintenance and reoccurring storm related backups and overflows, it was believed that I/I contributions from the Main 390 Drainage Area were resulting in excessive flows in the collection system. A comprehensive I/I investigation of the sanitary sewer collection system in the Main 390 Drainage Area was conducted to develop a cost-effective plan for sewer rehabilitation and to develop projections of rehabilitation costs required to alleviate I/I related overflows within the sewer system. The intent of the study was to identify sources of I/I and to present recommendations for reducing excessive I/I through proper management approaches such as sewer system rehabilitation, and selective relief or replacement sewers.

Background Of Study

Historically, the City has experienced problems with wastewater overflows and backups during periods of either short, high intensity storm events or prolonged rainfall events. In addition, dry weather overflows have been reported which were likely due to blockages in the collection system.

Problems occurring within the system included:

- Wastewater overflows and backups.
- Structural deterioration of pipes and manholes.
- Increased frequency of maintenance and associated capital expenditures.

Study Outline

The City commissioned the study to develop a pro-active rehabilitation program for minimizing the hydraulic impacts of I/I.

The first phase of the study was initiated in August 1995. Intensive manhole inspections, lamping inspections, large and small diameter pipe cleaning, smoke testing, dyed-water testing and closed circuit television (CCTV) inspections were conducted to characterize and quantify the defects within the collection system that contribute excessive I/I to the sanitary sewer collection system. In an effort to simplify tracking field investigations and quantifying I/I, the Main 390 Drainage Basin was further divided into 15 sub-basins.

During the second phase of the study, a flow-monitoring program was established to evaluate the hydraulic behavior of the collection system under various rainfall events and conditions. The main objective of this phase of the study was to quantify I/I rates for each sub-basin and establish a correlation between peak flow response and rainfall.

The third phase of the study involved development of a hydraulic model of all City owned sanitary sewer lines identified within the Main 390 Drainage Area. By creating such a model, the hydraulic impact of I/I on the existing sewer system could be evaluated for specified storm events. Where peak flows exceeded the hydraulic capacity of segments in the system, the model selected the appropriate relief/replacement sewers and determined the associated probable cost to implement the relief/replacement sewer plan for the drainage area.

The fourth phase included recommendations for a comprehensive rehabilitation program. Recommendations were based on records of excessive past maintenance problems and cost-effectiveness analysis (CEA) which identified the least-cost means of reducing excessive infiltration, transporting, containing, and treating the remaining peak flows under conditions that correlate to a specified rainfall intensity (or return period). This analysis included a combination of I/I reduction and relief/replacement sewers. The study was conducted assuming that all inflow sources, as well as all infiltration sources found to be cost-effective to eliminate, will be removed through various means of rehabilitation. Subsequent models were developed for various I/I reduction alternatives.

The fifth and final part of the study presented recommendations regarding the specifics of the cost-effective rehabilitation plan.

Basic study components included in each phase are shown in Table 1.

Table 1

General Components of the Study

Phase	Task	Purpose
I	I/I Investigation	Identifies and quantifies I/I sources in each of the selected sub-basins.
II	Temporary Flow Monitoring	Provides information regarding wet-weather flows. Temporary flow monitors in each sub-basin quantify gross I/I and help determine the relationship between rainfall and peak flow response (basin rainfall sensitivity).
III	Hydraulic Model	Allows computer simulation of hydraulic behavior of sanitary sewer system under varying storm events and I/I reduction levels. Identifies relief sewer requirements.
IV	Cost-Effectiveness Analysis	Identifies the "least-cost" option of I/I reduction through sewer rehabilitation and relief or replacement sewer plan.
V	Final Recommendations	Presents specific recommended improvements resulting from the Cost-Effective Analysis. Outlines the projected costs for system rehabilitation in the Main 390 Drainage Area.

METHODOLOGY

Typically, field data gathered during a SSES is entered into a database and tracked graphically using a CAD program. Normally, the time required for CAD mapping can become quite extensive. For our project, all field data collected during the first phase of the project was entered into a SSES database and hydraulic modeling program called Pipedream,® developed by Wade & Associates, specifically for sanitary sewers. At the beginning of the project it was decided that a GIS would be used to track information and provide graphics to be used for reporting. After extensive research, ArcView® was selected as the GIS package that would be integrated with Pipedream®.

Prior to the development of the ArcView® GIS we, as do many people, had the preconceived notion that the development of a GIS would be costly and very time consuming. Since the project was under the constraints of an AO, time was limited. We also wanted the GIS development to be reasonably close to the estimated cost of tracking our information using a common CAD system. Our intent was to develop a GIS to be used solely for the sanitary sewer system. No attempt was made to incorporate active themes for water lines, storm sewers, streets, lots/parcels, etc., resulting in reduced cost and time. We, however, knew that we would have a substantial learning curve ahead of us.

Implementation of the GIS began with the line-cleaning portion of the project. During the initial phase of the project, it was decided that 75% of the lines in the sanitary sewer system should be cleaned. In addition, 20% of the lines selected for cleaning would be televised for QA/QC purposes. Our goal was to systematically identify lines requiring cleaning rather than a random selection process. To do so, it was decided that sewer maintenance records, reported overflows, field investigation data, and isolated rehabilitation projects currently in progress would be identified.

The City's sewer maintenance records were reviewed and a list of lines requiring chronic maintenance efforts was compiled and entered into a database. Prior to the cleaning project, approximately 1030 manholes within the Study Area were internally inspected. During the internal manhole inspections each line entering and exiting the manhole was lamped in an effort to identify structural defects or other physical characteristics that may cause hydraulic deficiencies such as poor line grade or debris. Also, during field investigations, each sewer line was smoke tested. Each defect identified was logged onto standard field forms and entered into the database.

Our goal was to provide the City with a map that identified lines with; (1) excessive maintenance history, (2) smoke defects, (3) broken, collapsed or partially collapsed pipe, (4) moderate or heavy debris, (5) moderate or heavy root intrusion, (6) recently rehabilitated or replaced or currently scheduled for such activities, and (7) reported overflows. Once the map was developed, representatives from the City's engineering and maintenance departments met with the project engineer to discuss the lines recommended for cleaning. During the meeting, lines recently cleaned by the City were removed from the list and any lines known to have a troubled past history and not identified on the map were added. Following the meeting, a final list of lines to be cleaned and a map were provided to the cleaning contractor. Cleaning and CCTV activities were also tracked using the GIS.

So, what did we learn? As with any first time endeavor, we did a few things the hard way. We did, however, learn a few important lessons that have increased our productivity tremendously. Based on what we have learned so far, the following is a brief summary of how to get started:

CAD Mapping

A common perception by most novices is that GIS is a CAD system. Although some GIS packages do have tools to conduct automated drafting, the GIS package we have selected is not known for its sophistication in drafting capabilities. Therefore, we used AutoCAD® as our drafting software. The City provided us with AutoCAD® drawings which included sanitary sewer lines with identification labels, sanitary sewer manholes with identification labels, streets, street names, lots and blocks, streams, and railroads. Hydraulic modeling and defect data were stored in FoxPro® data files.

For our project only two features were selected to be truly active, sanitary sewer manholes and sanitary sewer lines. We displayed all other data as simple images. Data shown as images in ArcView® could be seen but could not be queried by selecting a feature such as a single lot or parcel. Each active element to be included in the GIS map must have an identification label. For simplicity, we used the City's current manhole numbering system for manhole identification labels. Each record in the database must have a field containing the exact identification label used to identify its corresponding feature in ArcView®. The line segment identification labels were a combination of the upstream and downstream manhole numbers. All data collected in the field was also identified with the City's manhole numbering system, providing the common link between the databases and the GIS.

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For active sanitary sewer line segments, the following characteristics should be established:

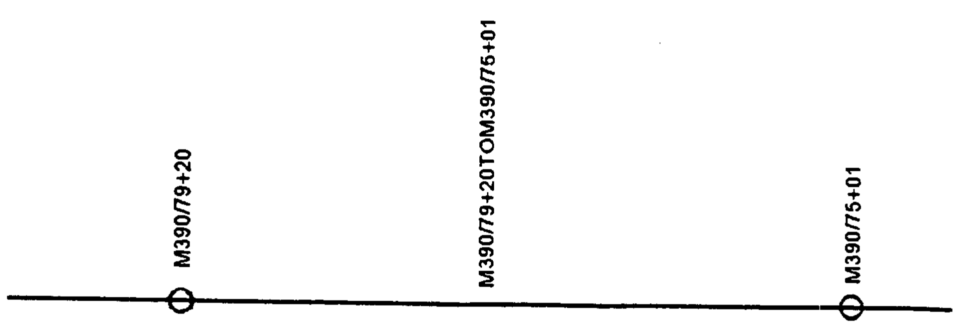
1. All sanitary sewer lines should be on a single layer with no other information.
2. Each sewer line must be drawn as a polyline and connected from end-point to end-point. It may also be helpful to draw the line from the upstream manhole to the downstream manhole. This practice is not absolutely necessary but if you want to develop a hydraulic model from tables created by ArcView®, the data will have the appropriate connectivity.
3. Each line segment must have a unique identification label. That exact identification label must be contained in the database for each record the user wishes to link to a feature. This label must be an attribute block and connected to the sewer line. To prevent overlapping of labels, we found it helpful to label the lines at the midpoint.
4. All sewer line labels must be on a single layer with no other information.

For active sanitary sewer manholes, the following characteristics should be established:

1. All sanitary sewer manholes should be on a single layer with no other information.
2. All manholes must be drawn as a point.
3. Each manhole must have a unique label. Each label must be an attribute block and connected directly to the manhole point.
4. All manhole labels must be on a single layer with no other information.

An example of the sewer line and manhole identification is shown in figure 1.

Figure 1.



We have yet to find a CAD document prepared by a municipality with the anticipation of being used for a GIS. Therefore, each sewer line and each manhole must be redrawn.

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All non-active information that you would like to display should be on a layer by itself. For example, if you would always like to show the streets and lots/blocks at the same time, they should be on the same layer. Street names may be located on a separate layer so the user can turn them on or off. It is wise to select the size of characters you want to display in ArcView® while you are in AutoCAD®. ArcView® will allow you to change the character font but will not allow you to change the character size. A list of common non-active display layers is shown in Table 2.

Table 2

Common Non-Active Display Layers

Item No.	Display Layer	Item No.	Display Layer
1	Sewer Line Identification Text	6	Railroads
2	Manhole Identification Text	7	Study Area Boundary
3	Streets/Lots/Blocks/Parcels	8	Drainage Area Boundary
4	Street Names	9	Drainage Area Sub-Basin Boundary
5	Streams	10	Orthographic Images

ArcView® can view CAD images in either of two methods, as a shape file or from a permanent shape file. Each method has advantages and disadvantages. If the CAD file is read directly by ArcView® and a shape file created each time the project is opened, any changes made to the CAD file will automatically be recognized by ArcView®. The disadvantage to this method is that more time is required when opening a project in ArcView®. If a permanent shape file is created by ArcView® from the CAD file, the project will open much quicker but changes are not automatic. The user must recreate the permanent shape file each time the CAD file is changed. As a general rule of thumb, we have found it much faster to create the shape file directly from CAD on projects where multiple changes will be required. If the shape file will be created each time the project is opened, it is possible to delete all of the tables before saving the project. The tables will be recreated each time the project is opened, saving valuable time.

GIS

Before the user determines the appropriate procedures for developing the GIS, they should consider the use of the GIS for future projects. As a consultant, it is important to implement a GIS shell that is somewhat generic and can be applied with few modifications to multiple projects.

ArcView® will allow the user to define multiple views for each project. A view is an interactive map that lets you display, explore, query, and analyze geographic data. For our project only one view was developed.

For our project, ArcView® was used only as a graphic viewer. Each piece of active information that the user would like to display, such as a manhole or sewer line, is considered a feature. Each feature must come from a feature source that may include individual layers from a CAD file, an orthographic image, photographs, or clip art. Each active feature to be displayed must be one of four types; (1) a point, (2) line, (3) annotation, or (4) polygon. Features may also be geocoded in ArcView®. Geocoding is a method of attaching active points, or features, to a map, using ArcView®.

For our project two types of active features were used, points for manholes and lines for sewer lines. All other images displayed were non-active. The point and line files were joined using ArcView® to form a shape file. After the shape file is created, it can be opened as a table. Additional data fields may be added to the tables to be used for display purposes.

Once the shape files have been created, themes must be created to display the data contained in the shape files. ArcView® features a table of contents containing a list of available themes for each view. For themes that the user will always keep in the table of contents, such as sewer lines, manholes, or study area boundary, the themes should be created and saved with the project. Each time the project is opened, the themes will be displayed in the table of contents.

Data that may be constantly changing, such as data collected in the field and entered into a database, can be displayed by writing scripts that create themes used to display data. The scripts must be written in Avenue program language for use in ArcView®. If the information in the database changes, the themes will not automatically change. By deleting the themes and recreating them using the scripts, the current data will be displayed. The Avenue scripts can be added to the ArcView® menu for ease of use. Learning to write Avenue scripts can be quite time consuming. Several example scripts, which the user may find helpful, are provided with ArcView®.

ArcView® can create two types of plots, *layout* and *view only*. The most common method for plotting from ArcView® is by using *plot layout*. *Layout* will allow the user to select the paper size, orientation of the plot, title, legend and north arrow. ArcView® allows the user to save multiple *layouts* so a new *layout* won't have to be created each time a plot is desired. Plots may be sent directly to a plotter/printer or exported to a file. When exporting to a file, ArcView® creates a raster image, sometimes requiring a tremendous amount of memory. If no legend or title is required, the user can plot a *view only* image.

Resources

Developing a GIS did consume a substantial amount of time. Our effort can be broken down into two major tasks, preparation of the CAD maps and development of the ArcView® themes. Development of the ArcView® themes can be further divided into two categories, permanent themes and themes created from scripts. Keeping in mind that we were near the bottom of the learning curve for ArcView®, a summary of hours used to develop the GIS is shown in Table 3. Since the implementation of the Main 390 project, we have developed several other projects, each requiring much less development time. An estimate of hours required to develop the Main 390 project at our current location on the learning curve is also shown in Table 3.

Table 3

Project Resource Summary

Task	Actual Project Hours	Estimated Project Hours *
CAD Map Preparation	48	24
Creation of Permanent Themes	10	4
Creation of Scripts for Non-Permanent Themes **	220	2
Total	**278**	**30**

*- Estimated Project Hours determined based on substantial knowledge of GIS development
**- Significant learning curve for Avenue program language

Learning Avenue programming language required a significant effort. Since scripts written for the Main 390 project were generic, development costs were distributed among several projects, reducing the amount of hours billed to the project. As can be seen in Table 3, the time required to utilize the existing scripts for non-permanent themes is minimal compared to the initial theme development.

Based on the size of the Main 390 project, approximately 4 hours are required to input unique information into the databases, create the theme, and review for accuracy. Graphically tracking information, such as maintenance records, with ArcView® requires only a simple data entry and no changes to the CAD map, reducing the actual time required for each map by as much as 50 percent. We estimate approximately 8 hours would have been required if CAD maps were developed and checked for accuracy for each of our plots. If 4 hours were actually saved for each plot, using GIS will become cost-effective when 70 plots are created.

For our project, we anticipate in excess of 60 plots will be generated prior to submitting the Final Report to the City. In addition to the anticipated plots, several plots were required to show rehabilitation efforts from multiple design consultants. ArcView® will be used to track progress of the design consultants through completion of construction. Based on the interim project review and reporting requirements imposed by the client, we will exceed the 70 plots required. Since we use the GIS shell developed during the project for other projects, our savings is considerably more. If the GIS/database is provided to the municipality and continually used, the savings becomes even greater.

CONCLUSIONS

By utilizing a GIS, we believe we have enhanced our performance and improved the quality of project deliverables. Although our initial project resource savings were not substantial, we have proven on projects since, significant resource savings may be achieved.

By implementing a GIS as the initial phase of a project, field activities are easily tracked, eliminating the need for cumbersome master maps, which require daily updating. Although a GIS does require daily updating, it is quicker to enter the field data into a database, which is required anyway, and simply recreate the appropriate theme(s) than to highlight maps.

Following the old-fashioned methods of presenting project findings and recommendations using limited graphics and tables is inadequate by today's standards. There is no real comparison of the archaic reports of the past to the value of an active GIS provided to a client following project completion.

Implementation of a GIS can be seemingly exhausting. If a fully active GIS is the ultimate goal, months or even years may be required for such development. By providing some forethought, the GIS application we have described can be integrated with the ultimate goal, while still being useful within a short time frame.

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PARRIS ISLAND AM/FM/GIS

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ABSTRACT

To better manage its sewer infrastructure, the Marine Corps Recruit Depot (MCRD) in Parris Island, South Carolina, has implemented an automated mapping and facility maintenance management program with a geographic information system (AM/FM/GIS). This program consists of a link between ArcView 3.0 (the geographic information system), which views AutoCAD (automated mapping) files, and CASS WORKS (facility maintenance management program).

The primary goals of implementing this plan were to create physical inspection and inventory databases of the sewer infrastructure; update the sewer system AutoCAD map; and to have a linkage between the facility management program, where the databases were to reside, and the sewer map. The secondary goals were to make rehabilitation recommendations based on physical inspections, establish a preventative maintenance plan, and create a work order history.

Results of Implementation

The primary goals were achieved with a combination of a sewer physical inspection and the MCRD's existing database. Above-ground manhole inspections and television inspections were conducted for one-third of the MCRD's sewer system. Physical inspection databases for manholes and line segments were created in the facility maintenance management program as a result of the field inspections. Also, sewer and line segment inventory databases were created from a combination of collected data and the MCRD's existing data.

The MCRD's sewer map was contained on twenty-five different drawings. One seamless sewer map drawing was created to be viewed in ArcView 3.0. The sewer drawing was updated for those portions of the sewer system that were inspected. Updates to the sewer map included labeling both new manholes and sewer pipes, as well as abandoned manholes and sewer pipes.

The databases in the facility management program were linked to the sewer map structures. The result was an inter-related connectivity between the facility maintenance manager and ArcView 3.0. The advantage of ArcView is the ability to perform spatial analyses of the sewer system.

The secondary goals were achieved by performing rehabilitation and cost analyses on the collected data using cost analysis program functions in the facility maintenance management program. This task also served to prioritize rehabilitation based on severity and cost. A preventative maintenance plan was established in the facility maintenance management program to inspect the remaining structures in the sewer system. Future work orders will be generated listing the structures to be inspected. A work order history enables the MCRD to keep track of costs as related to repairs for each structure or overall costs for all repairs.

The end result is an AM/FM/GIS program that allows the MCDR to perform queries, spatial analyses, and cost analyses on the databases. The databases and sewer map will become updated as the entire system becomes inspected.

INTRODUCTION

To better manage their sewer infrastructure, the Marine Corps Recruit Depot (MCRD) in Parris Island, South Carolina, has implemented an automated mapping and facility maintenance management program with a geographic information system (AM/FM/GIS). This program consists of a link between ArcView 3.0 (geographic information system), which views AutoCAD (automated mapping) files, and CASS WORKS (facility maintenance management program).

The primary goals of implementing this plan were to create databases and inventories of the sewer infrastructure; update the sewer system AutoCAD map; and to create a linkage between the facility management program, where the databases were to reside, and the sewer map. The secondary goals were to make rehabilitation recommendations based on physical inspections, establish a preventative maintenance plan, and create a work order history.

To accomplish these goals, the project was divided into two phases. The first phase involved creating one seamless AutoCAD drawing, to be viewed in ArcView 3.0, from the 25 existing sewer drawing files. After viewing the new sewer drawing for consistency, it was linked to the facilities maintenance management program through ArcView.

The second phase included the following tasks; manhole and television inspections of the sewer system, building physical inspection and inventory databases, and analyses of the collected data with rehabilitation recommendations.

METHODOLOGY

Map Linking

In order to achieve the goal of linking the sewer system entities to the sanitary facility maintenance management software (CASS WORKS) a single project sewer drawing containing only the sewer system was needed. This was accomplished by combining 25 AutoCAD source drawings of the sewer, provided by the MCRD, into one seamless AutoCAD drawing.

The first step for creating a seamless AutoCAD drawing was to remove from each source drawing all title blocks, sheet borders, legends, etc. Also, the layer colors and entity colors of each source drawing were set and standardized. These were the initial steps for developing the seamless sewer layer drawing.

Next, the 25 individual source drawings were combined into one drawing. The source drawings were geo-referenced in a common coordinate system. This is important because the placement of each individual source drawing relative to one another in the seamless drawing becomes a semi-automatic and exact process, rather than a manual placement process based on the judgment of a CAD Technician.

The new seamless drawing was then edited to conform to translation specification. Before an AutoCAD drawing can be easily and cleanly translated into ArcView, it must adhere to specific topological, entity type, and layer specifications. For example:

- Manholes, line segments, force mains, and pump stations must be on separate AutoCAD layers. In the source drawings from the MCRD, these features were on the same layer.
- A single and continuous line segment must connect two manholes or two pump stations. This condition was not always true in the source drawing. Line segments along tile edges were broken between manholes. Elsewhere in source drawings, broken line segments were observed and there were cases in which a single line segment connects three or more manholes.
- Line segments must be digitized in the direction of flow. This condition was not inherent in the source drawings.
- Manholes and pump stations should be represented by AutoCAD attribute blocks with their structure number embedded in the attribute block as the attribute value. In the source drawings, the manholes and pump stations were represented as elementary AutoCAD entities, such as filled polylines, and the structure number was a simple text entity positioned near the structure.

The AutoCAD editing involved was a manual process. The seamless source drawing was traced over and its entities replaced by standardized entities on standardized layers. The resulting drawing adhered to an AutoCAD drawing specification that translated easily and cleanly into ArcView. A series of AutoCAD menus was used to facilitate the editing of the source drawing.

Once the editing process was completed, the seamless drawing (which is now the project sewer layer) was viewed in ArcView for consistency. After proofing for consistency, maps were printed and provided to the Depot for consideration in determining the line segments to be televised. Nine maps were provided, along with an index sheet, which contained geographic areas/grids of the MCRD for each map. Also provided was a line segment listing by grid that was generated from ArcView.

In order to reference one force main intersection from another, a reference point was required where force main symbols met at an intersection or did not have a point where it intersected a pump station. To complete this task, nodes and node numbers were placed at each pump station where force mains begin or end and at the intersection where force mains joined together.

The last phase of the map linking involved linking CASS WORKS to the sewer layer in ArcView using a series of ArcView operations. Once this linkage was established, GeoCAD enabled CASS WORKS to be directly accessed from ArcView, or ArcView to be directly accessed from CASS WORKS.

FIELD INVESTIGATIONS

The field investigations consisted of above-ground manhole inspections which were performed in conjunction with the television inspection of the gravity sewer lines.

Manhole Inspections

The purpose of this task was to visually inspect sanitary sewer manholes and record the materials and condition of the manholes. In addition, this task served to update the AutoCAD sewer drawing based on a physical survey of the areas inspected. The MCRD sewer system is divided into a system of 25 grids, with 193 manhole inspections conducted in 11 of the grids.

The manhole inspections were conducted from above-ground and all observations recorded on standard Manhole Inspection Forms. The manhole inspections focused on specific areas of observations. For example, the inspection differentiated between the condition and type of defect (e.g. cracked or deteriorated), construction, and evidence of inflow among the frame, frame seal, and corbel. A rate expressed in gallons per minute (gpm) was assigned to each defect during inspection if active. If inactive a rate was expressed by a default value based on manhole location, location characteristics, and defect type.

The manhole inspection for this project was divided into seven specific areas. The following lists an overview of the specific areas with their corresponding recorded observations.

- Manhole Surrounding Area - Type of precipitation, ground condition, manhole location, and location characteristics.
- Cover Description - Type, cover to rim fit, diameter of clear opening, cover bearing surface, number of holes in cover and size, grade elevation, and evidence of inflow.
- Frame - Condition, frame adjustment construction, frame to corbel seal condition, and evidence of inflow.
- Corbel - Construction, condition, and evidence of inflow.
- Walls - Construction, condition, and evidence of infiltration.
- Bench/Trough - Trough construction, trough condition, bench deposition, evidence of infiltration, pipe seal condition, and evidence of infiltration.
- Miscellaneous - Step condition, surcharged at time of inspection, evidence of surcharging, and indication of groundwater level.

Three additional observations were also recorded, which is not part of the standard Manhole Inspection Form, during the inspection. The number of laterals within each manhole and whether a manhole contained a rainguard or was previously grouted were recorded. These additional observations helped update the new sewer source drawing and the MCRD records of maintenance previously performed.

Television Inspections

This task consisted of conducting a physical survey of selected gravity sanitary sewer lines. It also assisted in updating the sewer drawing and supported the manhole physical survey for the areas inspected.

A total of 31,603 linear feet of gravity sewer lines were televised. All observations were recorded during the television inspection process. This included recording observations such as lateral location and position, identification and quantification of defects, and line segment length. During the inspection a rate expressed in gallons per minute (gpm) was assigned to each defect if active or by severity if inactive. If a defect was inactive and was not quantified during the inspection, then a default value was assigned based on the type of defect.

Observations were recorded electronically using a television inspection software, LineView with Video Capture for Windows. Video capture allows the user to capture images of defects in a digital format so that they may be viewed on a computer. An image becomes part of the database because it is linked to its associated line segment.

RESULTS

The results, analysis, and rehabilitation recommendations were based on utilizing specific program functions within ArcView 3.0 and the facility maintenance management program. ArcView 3.0 enables the user to perform spatial analyses. The facility maintenance management program's report writer is used to create television reports, cost analysis reports based on television inspections, and perform queries such as total length of sewer pipes televised

Spatial Analysis

The number of manholes and line segment lengths per grid of the entire sewer system were acquired using ArcView 3.0 spatial analysis functions and from the revised AutoCAD drawing from the field inspection phase. New manholes found during the field investigations were added to the AutoCAD sewer drawing. Adjustments to the location of an existing manhole, which in effect adjusts the length of a line segment, were only made in those cases where moving a manhole would not affect any upstream manhole locations. The spatial analysis also indicated there was a total of 94,307 linear feet of gravity sewer lines and 565 manholes for the entire sewer system.

The spatial analysis functions for ArcView 3.0 were also used to determine the total lengths of the force main. This consisted of determining the length of each force main from pump station to pump station and pump station to force main. Results of the spatial analysis indicated 50,343 linear feet of force main exist in the system.

Manhole Inspections

Data collected from manhole inspections was input into the facility maintenance management program to create a manhole physical inspection database for the MCRD. The manhole physical inspection module in which the database was created, is modeled after the standard Manhole Inspection Form. Therefore, all of the data collected was entered into the physical inspection database, including the three additional observations recorded.

A database for the entire system of manholes was also created in the sewer inventory module. The sewer inventory manhole database includes manhole number, manhole type, street name, location, map reference, remarks, as well as other manhole specific information. The information in the manhole inventory database varies depending on whether the data was provided from the manhole inspection or from the MCRD's existing data, or both. For those manholes inspected, the rim and invert elevations from the existing MCRD database were added to the manhole information entered from the inspection. If a manhole was not inspected, then only the manhole number, rim and invert elevations, and grid location from the existing database were added to the manhole inventory database.

The invert elevation from the MCRD's database was entered into the 'user defined' field in the manhole inventory and the rim elevation into the 'rim elevation' field. The depth was automatically calculated from the rim elevation minus the invert elevation. It was assumed that the rim and invert elevations were obtained from the same datum.

Manholes that no longer existed were removed from the sewer drawing to reflect accuracy, but were included as part of the manhole physical inspection and inventory databases. Manholes that no longer existed were included in the databases for possible future reference and as a matter of record to show that a physical survey was performed for those manholes.

Television Inspections

All observations recorded in LineView with Video Capture were uploaded into the facility management program. Television inspection reports were generated from the facility management program for each line segment televised. The first page of the television reports include the direction of gravity flow from upstream manhole to downstream manhole, length and diameter of pipe, tape index, street name or building number, remarks, and general observations. The second page of the television report contains a listing, in chronological order, of the observations recorded during the inspection.

Cost reports produced from the facility management program list the unit costs and total rehabilitation cost for each repair method. The unit rehabilitation costs listed are the ratio of the repair cost to removable infiltration in $/gpd and the ratio of the repair cost to length of pipe in $/ft. The reports recommends rehabilitation by choosing the rehabilitation method with the lowest $/gpd. The cost analysis and rehabilitation recommendations are based upon various factors such as repair methods, repair cost, length between joints, and number of laterals.

Preventative Maintenance Plan

A preventative maintenance plan was established in the facility maintenance management program to inspect the remaining structures in the sewer system. Future work orders will be generated listing the structures to be inspected. A work order history will enable the MCRD to keep try track of costs as related to repairs for each structure or overall costs for all repairs.

DISCUSSION

Maps were generated from ArcView that visually displayed the manholes and line segments, based on tables created listing manhole I/I severity and line segment infiltration, for each grid of the system where field investigations were performed. To identify manhole structures symbols of varying sizes and color were used to represent ranges of I/I severity. For line segments, different colors were used to represent ranges of infiltration severity. The resulting maps produced a visual representation of the clustering of manholes and pipe by extraneous flow severity. The benefit of this type of map display is that it enabled the MCRD to see visually where the greatest concentration of extraneous flow was entering into the system. This visual scenario of cluster concentration can be used for any criteria, such as the cost to treat ($/gpd) to determine where to proceed with rehabilitation based on the cost-effectiveness of repair and reduction of infiltration migration.

After all the data was entered, an analysis was performed on the manhole database which produced a listing of all defects, associated inflow or infiltration, cost to repair, and rehabilitation recommendation based on the type, location, and characteristic of the defect for each manhole. Tables were created which listed by grid number the results of each manhole rehabilitation analysis. Included on the tables were manhole construction, I/I quantification, cost of rehabilitation, unit rehabilitation cost in $/gpd, and recommended rehabilitation.

To generate rehabilitation recommendations of all defect sources as required by the MCRD, the cost to treat wastewater was set at $100/gpd in the cost analysis report.

The following were other considerations in determining costs and rehabilitation recommendations:

- A rehabilitation recommendation for a cost report is based on the most cost-effective rehabilitation method ($/gpd) from MH to MH (e.g. Fold & Form). Individual joint grouting and spot repairs are not considered as a MH to MH rehabilitation, but as a combination they are. If no MH to MH rehabilitation is cost-effective, then spot repairs or grouting is recommended if either is cost-effective. If neither is cost-effective then no recommendation is made.
- Being a study project, exact unit prices for the MCRD area were not determined. Repair costs were based on previous unit budgetary design/construction projects.
- Majority of repairs occur in paved areas or where unpaved areas are not easily accessible.
- Five feet is a nominal length for determining repair length.
- Recommended spot repairs (point repairs) may be needed before MH to MH rehabilitation begins. The need to perform each spot repair should be evaluated before the start of rehabilitation.
- The costs for spot repairs are not reflected in rehabilitation costs, when a different rehabilitation method (such as Fold & Form) is more cost-effective.
- All joints are recommended for grouting to prevent groundwater migration to unrehabilitated joints. Joints may not be active with infiltration, but may become active when the joints with visible infiltration are rehabilitated.
- Generally, the reduction in capacity from lining is not significant unless the system is already flowing at full capacity. The reduction in cross-sectional area is compensated by the reduction in friction.

Unit prices include the following estimated construction and related costs:

- By-pass pumping and dewatering
- Trenching and backfill
- Sheeting and shoring
- Nominal select fill and seeding
- Pavement removal and replacement

The rehabilitation methods considered for the cost analysis included fold and form, cured in place, complete replacement, joint grouting, and spot repair. The cost of repair for several methods were calculated so that during the construction bidding process, when the MCRD receives bids from contractors in their area of specialty, the cost report can be a barometer for the different types of construction bids that come in.

CONCLUSION

The end result is an AM/FM/GIS program that allows the MCDR to perform queries, spatial analyses, and cost analyses on the databases. The databases and sewer map will become updated as the entire system becomes inspected.

RELATIONAL DATABASE SYSTEM FOR IN-SEWER AND CSO MONITORING

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ABSTRACT

In urban hydrology, the refining of models for calculating sewerage system dynamics requires more and more numerous measurements which can be taken at time steps down to the order of a minute. Hydrologists and hydraulic engineers are now faced with the problem of managing, validating and processing these measurements or time series. We have developed a relational database application, which specifically addresses the problem of managing time series in urban hydrology.

The relational model contains three fundamental entities, which are the local station, the sensors linked to a local station, and the measurements taken by the sensors of a local station. With these three entities, the positions of time series in time and space are determined, which permits the establishment of relations among them and the identification of behavior expectations for the sewerage system. Complementary entities are also included which help grasp the more global aspects of the in-sewer flow such as its behavior during dry weather, rainy periods which are deduced from rainfall measurements, and the dynamics of the controlled devices.

A group of primitive functions makes it possible to validate and process the time series through a graphic interface. These primitives introduce various techniques such as splines, averaging and exponential filters, Manning's formula, etc. Once processed, the data can be used with a simulator, and exported or printed in various report formats. The database is an open system and its relational format renders the data accessible to any specific processing procedure.

The database was used for in-sewer and CSO on-line monitoring in the City of Paris (France). More thant 100 points were monitored simultaneously, of which 50 were permanent, the others were moved from one site to another after having recorded enough data. Measurements included water levels (at three levels) and water velocities. Flow was computed out of this data and with consideration from in-sewer sediment level data. Water quality data included suspended solids, BOD and COD, although the database accepts more water quality parameters.

This first application demonstrated the good representation of the relational data model the great performance of the query mode. Object-oriented modules were later added to enable data input in both on-line and off-line modes, and to validate and adapt to hydraulic or hydrologic simulation models. The time series can then be used for the model calibration, for system diagnosis, and for the design of new engineering structures.

KEYWORDS

Urban Hydrology, Relational Database, Combined Sewer Overflow, Monitoring, Data management, Local Station, Sensors, Measurements.

INTRODUCTION

In urban hydrology, activities such as monitoring, characterization, diagnosis, calibration, simulations and real time control require more and more measurements which become difficult to manage. The quantity of measurements, which can be taken at one minute time steps and often on a period of one year or more, easily attains a few million for each sensor. Hydrologists and hydraulic engineers are now faced with the problem of validating, storing, recuperating, and processing all this data.

A relational database becomes essential and seems to be the solution to efficient and reliable data management. A relational database enables a logical and conceptual description of elements such as sensors and all the associated data, eliminating the problem of having a multitude of files. Moreover, recent developments of database structure and Object-Oriented enables to recuperate and process data with simple query tools.

Having numerous experiences in urban hydrology activities using a great quantity of data, Asseau-BPR through CEGEO Technologies research program has developed a relational database specifically for this purpose including user-friendly interfaces with numerous functions to calculate, produce reports, link to models such as SWMM, graphically observe simulation results or measurements, etc.

The database called MED-DB was used in 1996 for in-sewer and CSO on-line monitoring in the City of Paris and Vicinity (France) (population: 8 million). More than 100 sites were monitored simultaneously, which 50 were permanent, the others were transferred from one site to another after having recorded sufficient data. Measurements included water levels (at three levels) and water velocity. Flow was calculated from this data and with consideration of in-sewer sediment level data. Water quality data included suspended solids, BOD and COD.

This first application and others since, have demonstrated the good representation of the database and the great performance of the query mode. This paper will present the database model necessary to secure and structure data as well as the interfaces developed to facilitate the query mode and the overall work in urban hydrology.

Database Model

Two qualities required for a relational database used in urban hydrology are the robustness and a great volume capacity. For these reasons, Oracle was chosen as the basis of our development, although other relational database software can be used along with the interfaces described in the next section.

The key to a good relational database is the simplicity and the quality of the logical structure of its model. This will assure stable and reliable performances for queries and will facilitate the management and maintenance. For example, when a database model contains too much relationship levels and inheritance, the performance of data processing is poor and queries are difficult to perform. On the other hand, a simple logic database structure enables the easy access to information and short time process. For the Paris project, MED-DB was used on an IBM RS 6000, the disk space used by the large quantity of data was 4.5 GIG and the response time to a query was less than 30 seconds and around 15 seconds in average.

In the MED-DB, the logical structure is very simple, it is based on the three fundamental field elements:

- Local stations
- Sensors
- Measures

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These three elements constitute the entities of the relational model. Among these three entities, relations of time and space are determined to properly represent reality.

In the database each entity is represented by a table, rows being the instance and columns being the attributes of the entity. Table 1 illustrates a simplified example of these tables.

Table 1. **Entities represented by tables in the database model**

Local station					
Identification	In service	Time of acquisition	Status (Permanent or Temporary)	Phone number or IP address	Localization (X,Y)
P1	96/04/25	11:23:44	P	4188665567	1432522,2002428
P2	96/04/25	11:23:51	T	4188665543	1432538,2002404
WWTP1	96/04/25	11:23:57	P	145.200.120.240	1432562,2002389
...					

Sensor						
Identificatio n	Local station identification	Channel	In service	Out of service	Absolute Minimum; Maximum	Acceptable Minimum; Maximum
Quality 1	P1	Q1	96/04/25	-	(0;120)	(30;100)
Flow 1	P1	F1	96/04/25	-	(0;7)	(0;5)
Quality 1	P2	Q1	96/04/25	-	(0;130)	(30:90)T
...						

Measure							
Local station identification	Channel	Date of acquisition	Duration (min)	Value	Validated value	Validation method	Validation status
P1	Q1	96/06/27	5	63,4	63,4	-	Valid
P2	Q2	96/06/27	5	-545	60	Frequency	Invalid
WWTP 1	F3	96/06/27	10	3,6	3,6	-	Valid
...							

This structure has been developed with the objective of query time saving. For example, the relations created between tables with foreign keys enables the access to data using only two tables at the same time, this reduces time of response. In fact, each measurement is independent from its sensor. Hence, measurements at one local station become a stream of measures without interruption and independently of its sensor and the local station. The relation between sensors and measurements, through the local station table, is used only for data validation.

A good relational database model is essential to ensure the security of data, to store it in a more convenient and logical manner and to reduce time of SQL queries. On the other hand, the database model with SQL is not enough to ease the engineering work behind all this data. Even if one is perfectly at ease with SQL queries, the data analysis, the data validation, etc. are not easily performed. The next section will present the user-friendly query mode of the MED-DB database that has been developed for this purpose.

Interfaces, the query mode

The query mode has been developed with one objective: facilitate the work of engineers. Once that a good relational database is developed, efficient and easy access, treatment, printing as well as storing data and results are possible with practical interfaces. The interfaces were developed in C++ Object-Oriented and Delphi. These software combine the performance of screen display and graphic quality (C++) to the rapidity of development and customization (Delphi). C++ Object-Oriented and Delphi software have the advantage of producing direct executables in compiled language to reduce management file time.

The database MED-DB is linked to 4 Work Modules : Monitoring, Modeling, Simulation-Optimization (MED-SOM), and Real-Time-Control. These Modules work in hand with a utility called MED-MEASURE. This utility is used for handling measurements, hence it is the main tool of in-sewer and CSO monitoring. MED-MEASURE is useful to observe and treat data and to prepare data for further steps such as simulations for diagnosis, design and operation. Only MED-MEASURE will be presented in this article. For more information on the Work Modules, refer to other articles in the present and in past WEF conferences.

MED-MEASURE is composed of a set of interfaces acting as a bridge between the database and the user. The query mode becomes simple because of the SQL pre-programmed queries. MED-MEASURE has the following main functionality:

- Data acquisition
- Validate data
- Data analysis
- Export data and reports

Data acquisition

With different research types(parameters, period, location), MED-MEASURE can retrieve data from the MED-DB or from any other database. Furthermore, field data can be recuperated and integrated in the entity tables in real time or in differed time. Furthermore, the user can pre-program a field data retrieval at each chosen time step. This direct data acquisition reduces risk of errors and minimizes the engineering time normally needed for these operations. A first interface enables to retrieve data and an other to visualize the data arriving graphically as time series.

When data is retrieved in differed time, data is read by a standardized format file, as it is done in most software. The files are read, measures are verified, according to predefined validation, and they are integrated, file by file by the SQL Loader tool furnished by Oracle. In real time data acquisition, a communication is established between the database and the local station, and measures are directly transferred into the database tables with automatic verification of data. In both cases, the local validation is predefined with upper and lower acceptable limits.

Data validation

Although sensors are more and more robust, communication breakdowns, calibration default, etc. often occur. Therefore, the user must be able to validate or invalidate and replace data. According to the graphic interface the user can choose a time series for which he will identify non-valid data. The invalid data or time zone is selected with scroll bars and can be invalidated and replaced with new data. Figure 1 and 2 show the interface for selecting a time series and the data validation interface. MED-MEASURE provides different validation methods to replace invalid data such as:

- Duplication
- Interpolation
- Filtering
- Thresholding
- Flow recalculating
- Fitting curves
- Orthogonal search (for signal reconstitution)

The validation results can be saved in the database as well as the original time series. A registered measure in the database contains the original value, the validated value and the validation method used. The user is able at any time to recuperate original time series for equipment verification or revalidation.

Data analysis

Figure 3 shows the interface which enables the user to display multi-curves of any type of data. The user can elaborate its one graphs along with its needs of comparison. Measures can be compared to simulation or calibration results. 6 different variable types can be displayed and 14 different time series. To facilitate different analysis, the user has the possibility of choosing his templates, whereas axis, time zones, parameters, etc. are variable. The templates developed by the user can be saved and retrieved.

Rainfall analysis can also be done, whereas highs, maximum intensity, frequency, etc. are automatically calculated. Figure 4 illustrates the interface developed to select rainfall events along with their calculated characteristics.

Export data and reports

Data treatment is often used to prepare input for future analysis. Validated measures are available for these studies through the other modules with an export program that transfers data in table format. For monitoring campaigns and preliminary analysis, treated and untreated data can also be printed as graphics or as reports through other modules or directly through MED-MEASURE.

CONCLUSION

The database MED-MEASURE has been utilized with success for different projects. For the Paris project, MED-MEASURE became essential to manage 500 sensors for 100 sites of which 50 were permanent for a campaign that took more then one year. Automatic data processing on top of usual data treatment processes was useful to validate and take advantage of the 4.5 GIG of field data. These measures and the same database is know used for a diagnostic for the Ile-de-France Region (Paris and surroundings) whereas the same measures are transferred to the Mouse and Caredas simulation models. The Ile-de-France Region project is a good example were the database enabled to evolve from a monitoring campaign towards a diagnosis. The evolving aspect of the database will enable also to facilitate a further step towards Real Time Control.

The development of a database such as MED-MEASURE is not a scientific breakthrough, useful database software development exists for that matter and facilitates database development. The interest of this database is not the development but the result it answers specific needs in urban hydrology that is to facilitate data management.

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Figure 1. **Selection of a time series**

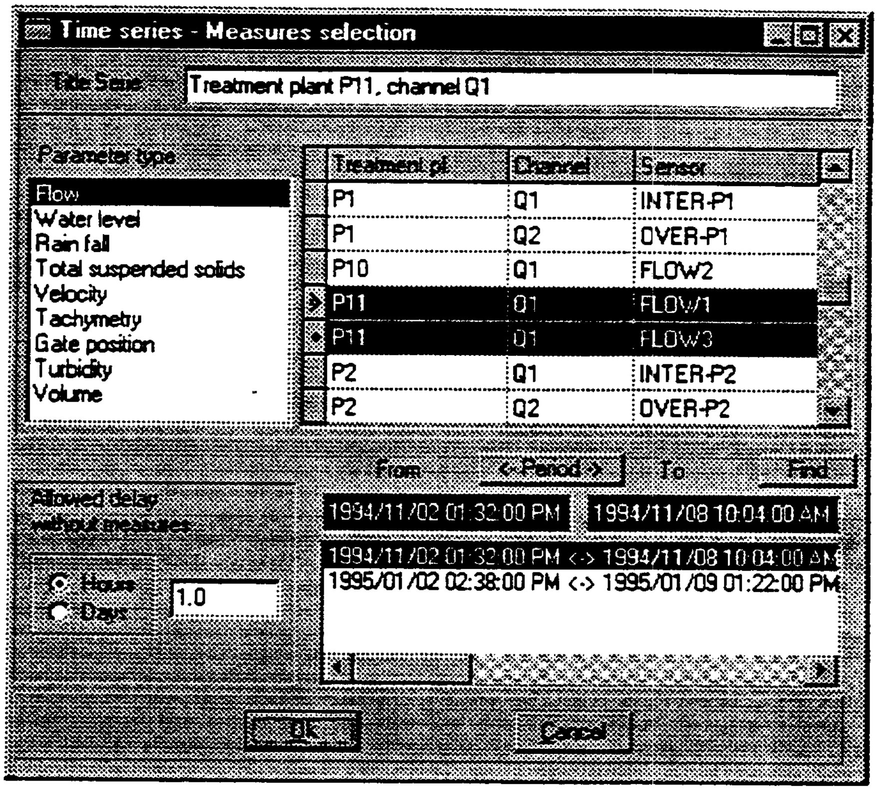

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Figure 2. **Data validation**

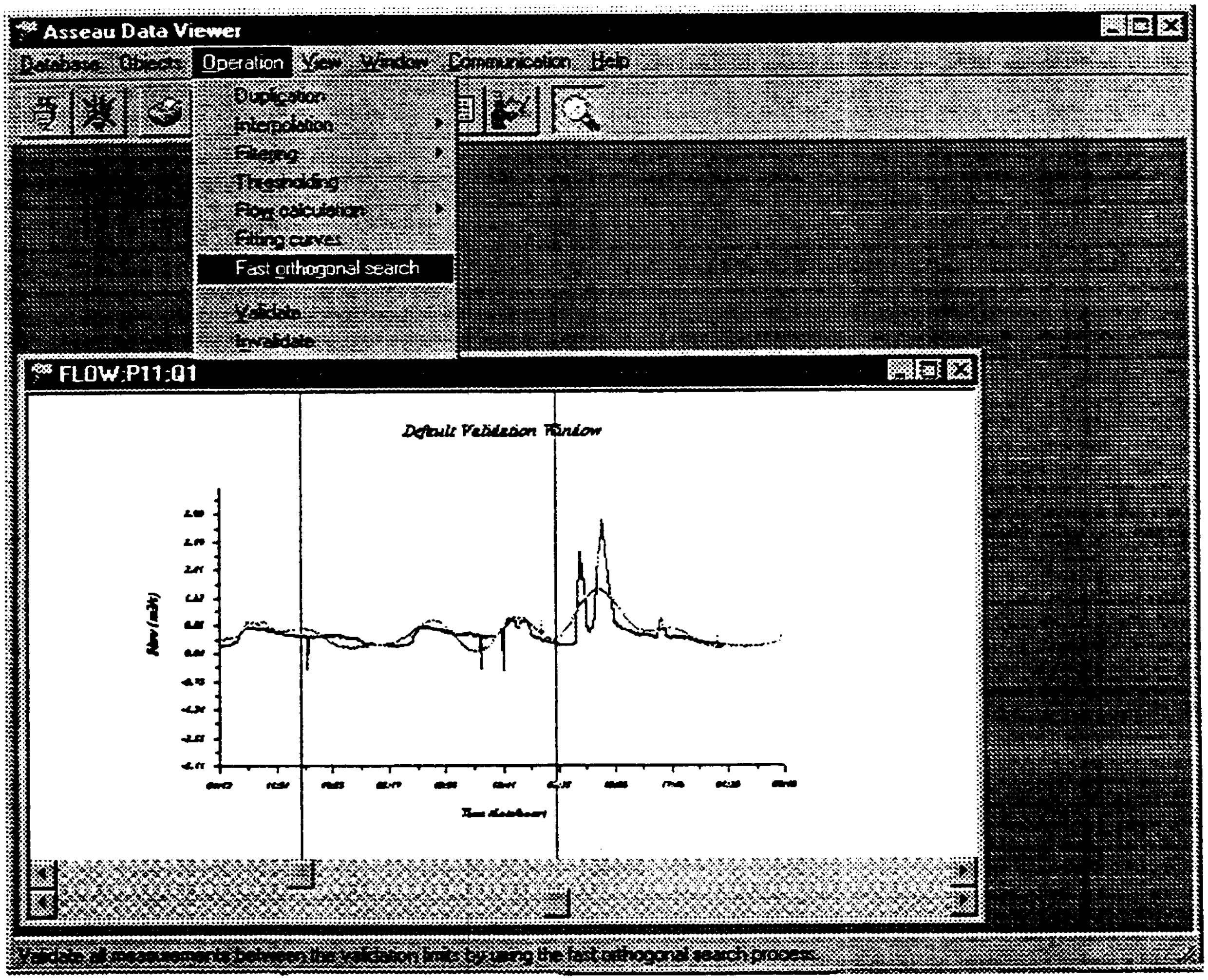

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Figure 3. **Multi-curves display**

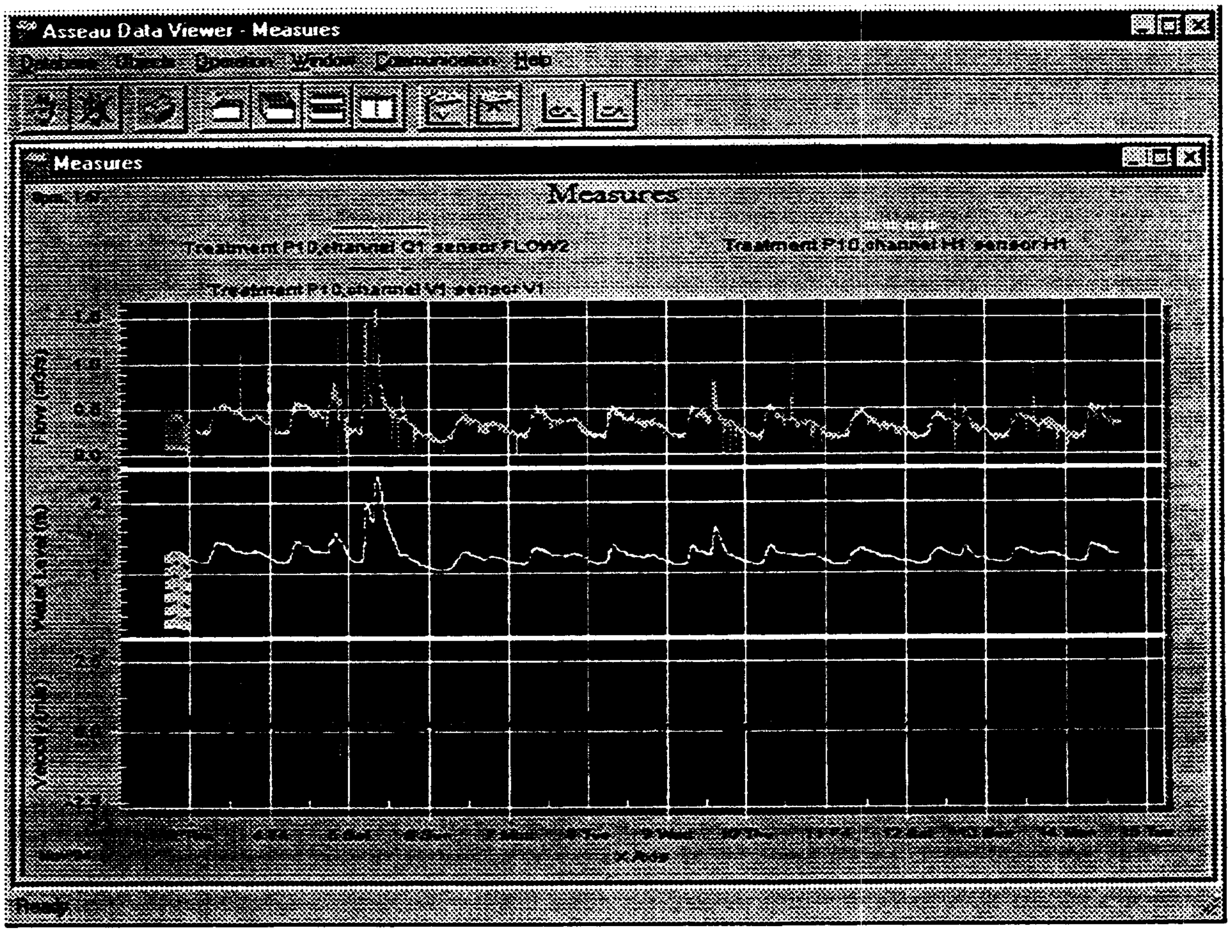

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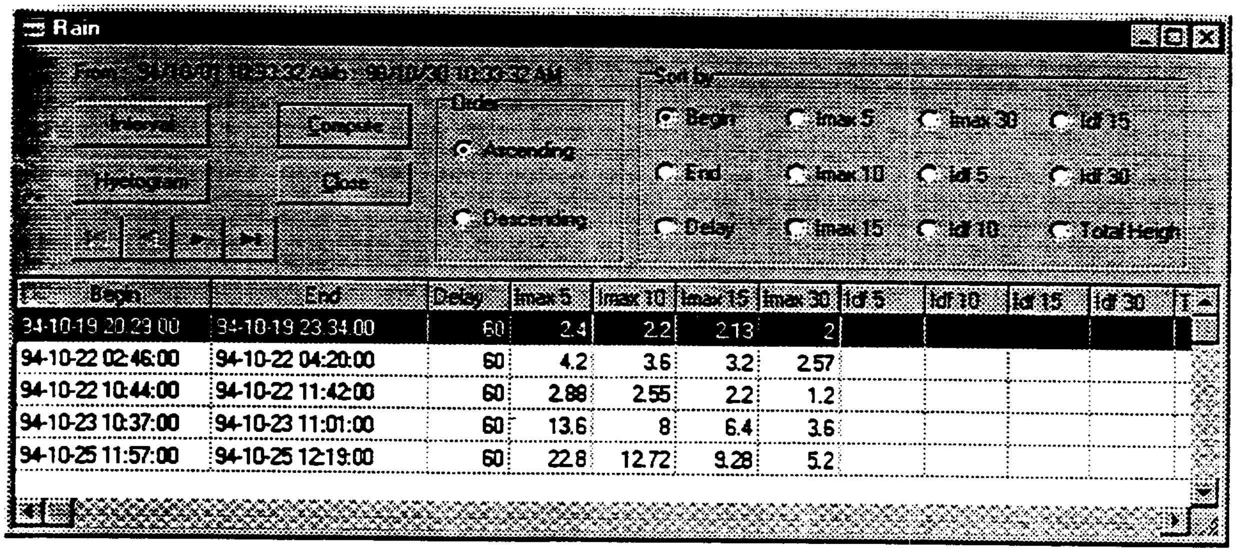
Figure 4. Selection of a rain full event



A DESKTOP GIS/HYDRAULIC MODELING APPLICATION FOR SSO REDUCTION

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ABSTRACT

Desktop mapping systems, also known as Desktop GIS, have improved greatly in power and functionality in the last few years. Geoprocessing that would have required tens of thousands of dollars in hardware and software just five years ago can now be performed on a mid-range desktop system with about fifteen hundred dollars worth of software. Further, the software is easier to learn and use, and a wider variety of data formats is supported, making Desktop GIS a very attractive platform for some sophisticated geoprocessing in support of environmental engineering studies.

This paper explores the application of a Desktop GIS to the East Baton Rouge City/Parish Sanitary Sewer Overflow Corrective Action Plan. While the GIS was instrumental to all phases of the process, including data collection/translation, database development, hydraulic modeling, model calibration, and options development, its key functionality was in the areas of overlay analysis and network tracing. Overlay analysis was used to allocate residential population from the census data to the sewer subbasins, and to compile a breakdown of land use by sewer subbasin. Network tracing was implemented to a) characterize the area upstream of a point, such as a pump station or flow meter; and b) to select facilities downstream of a point, for example to determine which facilities must be in a model for a selected area.

Other tasks the GIS was employed to perform include:

- QA/QC of survey data through automated profiling
- Calculation of storage volumes
- Calculation of angular head losses
- Export of model input files
- Import/display of model results

The desktop system was able to handle a large amount of data. Over 35,000 manholes and pipes, about 400 pump stations, 1200 subbasins, 350 census blocks and 10,000 land use polygons were in the study. This project proves that it is possible to build an effective GIS without spending a lot of time and money, and that the investment in Desktop GIS can save an incredible amount of time in the hydraulic modeling process.

KEYWORDS

Hydraulic modeling, geographic information systems, wastewater, sanitary sewer overflow

INTRODUCTION

The East Baton Rouge Sewerage Commission (EBROSCO) is responsible for sewerage services for most of the Parish of East Baton Rouge and all of the City of Baton Rouge, Louisiana. In anticipation of Federal EPA requirements concerning Sanitary Sewer Overflows, EBROSCO initiated an SSO Corrective Action Plan, a two-year study involving water quality monitoring, flow monitoring, system data collection, and hydraulic modeling, with the goal of eliminating sanitary sewer overflows.

THE HYDRAULIC MODELING PROCESS

Because of the expanse and complexity of the EBROSCO sewer system, a sophisticated. dynamic computer model was required to analyze the system and plan corrective measures. The Hydroworks hydraulic model by Wallingford Software was chosen because it can handle a manifolded pressurized main system and real-time control options. The hydraulic modeling process is very data-intensive. Steps in the process include data collection/translation, database development, model calibration/verification, and solution options development. It was immediately obvious that some sort of Geographic Information System (GIS) would be required to manage and process all of the data.

This paper examines the application of a Desktop GIS to the hydraulic modeling of the sanitary sewer system in Baton Rouge, Louisiana. The focus will be on some sophisticated GIS functionality that was not available on the desktop until fairly recently.

GIS: THE SOLUTION FOR DATA HANDLING

Desktop GIS systems have come a long way in the past ten years. What started out as very basic GIS data viewers have evolved into fairly powerful systems capable of some sophisticated GIS functionality. ArcView GIS by ESRI was chosen for this project because of its capabilities, low cost, and ease of customization through its Avenue programming language. This paper focuses on two key GIS functions:

1. Overlay Analysis, and
2. Network Tracing,

but first, let's look at the GIS data structure.

GIS Data Structure

This GIS implementation utilizes a classic node-link "tree" structure, with polygonal area themes as the "leaves." Nodes include any point-type feature, such as manholes, pump stations, flow monitors, etc. Links include anything that conveys sewer flow from one node to another, such as pipes, force mains, pumps, weirs, orifices, and the imaginary subbasin-to-manhole linkages. Area themes include subbasins, land use, and census blocks. Subbasins are the basic unit of area in a hydraulic model.

Overlay Analysis

A critical input to the hydraulic model is residential populations by subbasin. This can be derived from the census data, by overlaying census blocks and subbasins, assuming that a population distribution can be defined. Another critical input is a breakdown of land uses by subbasin. This is a straightforward overlay of land use and subbasins.

Components of the overlay process described herein are:

1. Census Data in MapInfo Format
2. Land Use Data Digitized in Microstation
3. Sewer Subbasins Digitized in ArcView

The census data were translated to ArcView shape files. The land use data could have been used in its original Microstation format, except for a problem with "doughnut" polygons. "Doughnut" polygons are polygons that completely surround one or more other polygons. In the overlay process, the ArcView routine cuts these "doughnuts" incorrectly. Nonetheless, it was easy to translate the Microstation files to ArcView shape files so that the topology could be corrected (no "doughnuts") in ArcView. Sewer subbasins were digitized right in ArcView, with sewers, streets and land use in the background for reference.

An overview of the overlay process is as follows:

1. Census and land use are overlain to produce a population distribution map.
2. The resulting population distribution map is checked against the original census data, and
3. Subbasins and the population distribution map are overlain to derive:
   a. Residential population of each subbasin, and
   b. Land use breakdown of each subbasin.

Population from the census is moved around based on land use weighting factors. No population is moved from one census shape to another, and the sum of the populations of the resulting fragments for a given census shape is equal to the original, given population of that census shape.

The land use weights are relative to each other, and do not have to add up to any particular number. In this case the single-family residential number is set to 1.0 and all of the others are related to this. See Table 1 for an example.

Table 1. Land Use Weighting Factors

Land Use	Land Use Weighting Factor
Single Family Residential	1.0
Multi-Family Residential	2.0
High Density Residential	3.0
Rural Residential	0.25
Industrial	0.05
Park	0.0
Commercial	0.1
Agriculture	0.1

The output theme has all of the fields and information in the two input themes, plus more. The additional derived output information includes each resultant polygon's area, population, and population density. This theme must be checked to ensure that no population has been lost, and there are no unrealistic population densities caused by aberrations inherent in the overlay process.

Items to check in the output theme include:

1. Attach the same population distribution legend as on the census theme to this theme. First make the "Classification Field" the same as in the census theme. The picture should look exactly like the original census, except for more polygon outlines.
2. Attach the same land use legend that you have on the land use theme and compare to the original land use. They should match.
3. Look for unreasonable population density values.

Residential population from the population distribution theme is aggregated by intersecting the theme with the subbasin theme, and multiplying the fragment density from the population distribution theme by the resultant fragments' areas, and then summing up. Landuse breakdowns are simple additions of fragment areas for each land use.

The output table has all of the fields and information in the two input tables, plus each resultant polygon's population, area, and population density. The output theme and table are intended for checking purposes only. The population and land use data are put directly into fields in the input subbasin table.

The processing of this overlay analysis takes place in two customized Avenue scripts. The sample script named "intersect.ave," which is provided with ArcView, was modified to include the area-weighting calculations used in generating the population distribution map. The same sample script was also used as a base for the subbasin population calculation step. See Figure 1 for an example of the analysis of one census district.

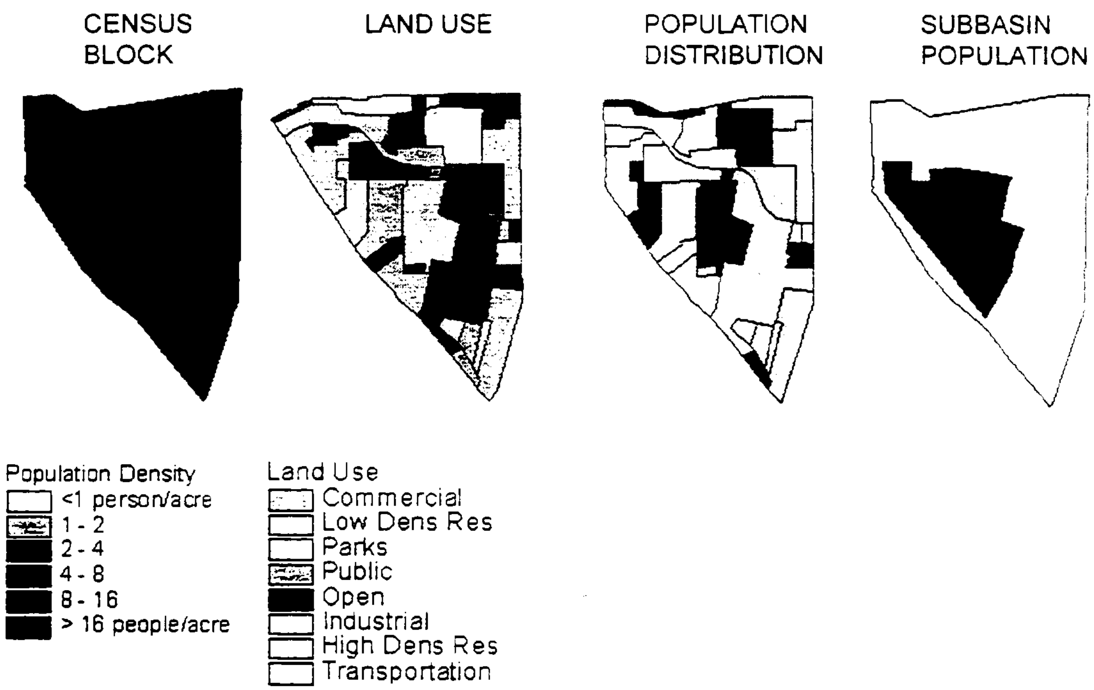

FIGURE 1. Population Distribution by GIS Overlay Analysis. For clarity and simplicity, only two subbasins are shown. Note that the residential population density is highest in the residential land use areas.

Network Tracing

Network tracing is the process of selecting elements upstream or downstream of an element based on directional connectivity of the network. There are two fundamental reasons for tracing up or downstream:

1. Tracing Upstream:
   To characterize the area upstream of an element, such as a manhole, pump station, or flow meter.
2. Tracing Downstream:
   To select facilities downstream of a point, for example to determine which facilities must be included in a hydraulic model for the selected area.

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Tracing is performed by an Avenue script that iteratively searches through the links table, which contains fields for upstream and downstream-side node identifiers (record numbers). These identifiers are unique for each node in the system. When a downstream search is at a link with downstream node number 2351, a query is issued to select all links with an upstream node number of 2351. These links then go into a list of links to process. The whole process moves hand-over-hand up or down the system until there are no more links left in the list of links to process. Then connecting manholes are selected, and, if it is an upstream trace, connecting subbasins are selected as well.

The obvious application for this process is in the selection of facilities to model for a given area. The user may select the subbasins to model, trace down, and then export a hydraulic model based on the selected subbasins, links, and nodes. Alternately, the user may select a point, for example a pump station, trace up to select the contributing subbasins, and then trace down to extract the required facilities to include in the model.

MODELING

The modeling process is made up of five steps:

1. Element Selection / Model Export
2. Model Running and Import of Results
3. Model Calibration and Verification
4. Model Simplification
5. Solution Options Development

Element selection and model export are performed as described in the network tracing section. The model export process writes a text file in a format readable by the hydraulic modeling program, which then reads this file and verifies the data. The user may then run the model. Hydroworks puts out a text file summarizing hydraulic grade lines, flow velocities, and flow rates for each facility in the modeled system, which are then read back into GIS tables.

In the calibration process, the user views model result graphs and compares them with recorded graphs at the flow monitors, and makes adjustments to such things as groundwater infiltration, dry-weather flow profiles, fast and slow-response contributing areas, in an effort to make the model results match the recorded flow. This GIS implementation facilitates this activity by allowing the user to select subbasins to edit based on the flow monitor immediately downstream. The model result graphs and recorded graphs and subbasin data can be displayed on screen all at once, allowing the modeler to quickly make edits to the subbasin data to make the results fit the recorded data. See Figure 2 for an example.

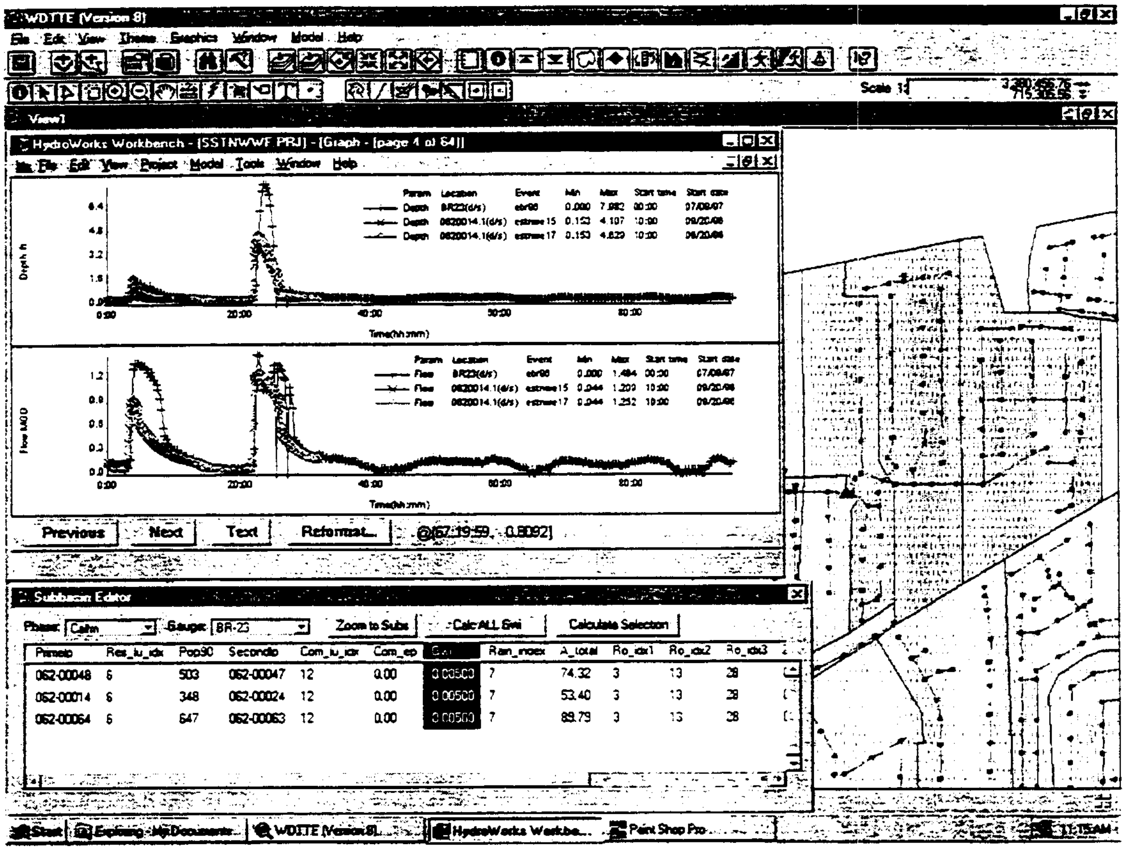

FIGURE 2. Model Calibration. The user selects a gauge in an ArcView dialog and the subbasin data for the area tributary to that gauge is immediately accessible for modification.

Once the model has been calibrated and verified (tested with data from different rainfall events), the model is simplified by generalizing the facilities, that is, taking out as many nodes as possible without affecting the hydraulic response of the model. This simplified model is then used as the base model for options development.

SUMMARY

With this desktop GIS/Hydraulic modeling system we have been able to perform some sophisticated geoprocessing, including overlay analysis and network tracing, in support of hydraulic modeling. Just six years ago, this functionality required a $30,000 unix machine running $10,000 worth of GIS software. Now the same can be done on a $3000 PC with $1200 worth of GIS software.

ACKNOWLEDGEMENTS

This project was funded by the East Baton Rouge City/Parish Sewer Commission. The authors wish to thank Andrew Baldwin of Montgomery Watson for the nuts and bolts of the model export/import routines, and Neil Moody, also of Montgomery Watson, for the loan of his modeling expertise.

UTILIZATION OF GIS IN HYDRAULIC MODEL BUILDING PROVIDES NUMEROUS BENEFITS

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ABSTRACT

Many SSO and CSO programs require the building of a hydraulic model for the evaluation of sewer system response to dry and wet weather conditions. These models require the collection, storage and utilization of large quantities of data that will be available from numerous sources and in varied formats. In New Orleans, the collected data was integrated into a GIS system that will aid in the development of the model and provide a tool for future facility planning, design and operation.

Model data was collected from the following sources and converted to an electronic format for integration into the GIS.

- Paper sewer maps for location of sewers, lengths and connectivity
- Physical surveys for manhole elevations, pipe sizes and invert levels
- Systemwide network of flow monitors for system response to dry and wet weather conditions
- Physical inspections and paper records for details of pump stations and other structures (i.e.. siphons)
- Paper zoning maps
- Digital land use maps
- Digital census data
- Pump curves
- Aerial ortho-photography
- Digital water use database
- Digital collection system inventory and work activities database
- Digital two-line streets maps for background mapping

Utilization of a GIS to collect and store the converted data in a single location will not only ease the model building and calibration process, but will result in secondary benefits to the operator long after the modeling phase of the project is complete. The GIS benefits include: single location of collected data, direct download of data to the model, geographical display and interrogation, connectivity quality checks, and review of data before it is entered into the model. System design and operations staff are provided with a useful infrastructure management tool that may not have been developed were it not for the need to develop the hydraulic model as part of a wet weather control program.

KEY WORDS

Hydraulic Model, GIS, Wet Weather, Sewer Rehabilitation

INTRODUCTION

The Sewerage and Water Board of New Orleans (S&WB) has turned a mandate to rehabilitate their sewer system into an opportunity to develop a useful graphic information system (GIS) database that will help manage existing and future system planning and maintenance functions.

The strategies and processes utilized by the S&WB to convert numerous information sources into a single integrated Arcview based information system should provide a useful blueprint for other water and wastewater utilities to utilize a GIS database and automated applications to better manage and run their facilities.

BACKGROUND

New Orleans, the largest City in Louisiana, is located near the mouth of the Mississippi River on the Gulf coast. Most of the City lies below sea level and is protected by a system of natural and man-made levees. The City's average annual rainfall of 1476 mm (58.12 inches) is exceeded by only one other metropolitan area in the country. The unusual topography and high annual rainfall that generally comes in frequent, high intensity deluges create special challenges with respect to drainage and sewage conveyance.

The wastewater system has evolved through many additions and improvements since its inception around the turn of the century. The system, which is operated and maintained by the S&WB, services an area of approximately 220 km^2 (86 sq. miles) and a population of approximately 497,000. It consists of over 2080 km (1,300 miles) of gravity collection and trunk sewers ranging in size from 200-millimeters (8-inches) to 2100-millimeters (84-inches) in diameter and over 160 km (100 miles) of force mains ranging in size from 150-millimeters (6-inches) to 1800-millimeters (72-inches) diameter. There are 83 pump stations which help convey wastewater to the City's two wastewater treatment plants on the East and West banks of the Mississippi River with a combined capacity of 500 megaliters per day (Ml/day) (132 million gallons per day (mgd)).

During the 1970s, the S&WB concentrated their financial resources on wastewater improvements at the East Bank plant, increasing its capacity from 87 Ml/d (23 mgd) to 461 Ml/d (122 mgd). The 38 Ml/d (10 mgd) West Bank plant is in the final stages of an expansion that will double its treatment capacity.

With the treatment plant expansion program successfully nearing completion, the S&WB is now focusing on the capital improvement needs of its aging wastewater collection system.

SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM

In response to regulatory pressures and the desire to provide excellent customer service and protect the waters of Lake Pontchartrain, the S&WB has embarked on a multi-year systemwide sanitary sewer rehabilitation program aimed at restoring structural integrity and improving wet weather performance. The program, named the Sewer System Evaluation and Rehabilitation Program (SSERP), is comprehensive in nature and will likely result in over $200 million of system rehabilitation and capacity upgrade construction.

Early in the SSERP process the S&WB recognized that a successful, cost-effective capital program required careful and thorough planning to provide a complete understanding of system behavior during both dry and wet weather conditions. An essential requirement in achieving that understanding is the development of an accurate, systemwide, dynamic, hydraulic model. This hydraulic model will predict system response to dry weather conditions and, more importantly, to the frequent short duration but high intensity rainfall experienced in this Gulf coast city. The model will help identify stress points in the collection system and confirm the viability of possible solutions.

MODEL DATA REQUIREMENTS

A typical modeling process, as depicted in Figure 1, begins with the collection of data and ends in the development of a Corrective Action Plan. The reliability of the model output to accurately predict the behavior of the wastewater system during wet weather events is founded on accurate, organized and properly formatted physical system data.

The recent improvements in computing power have allowed increased sophistication in the detail included in computer hydraulic models of sewer systems. This heightened sophistication has lead to increased requirements for the collection, storage and analysis sewer system data.

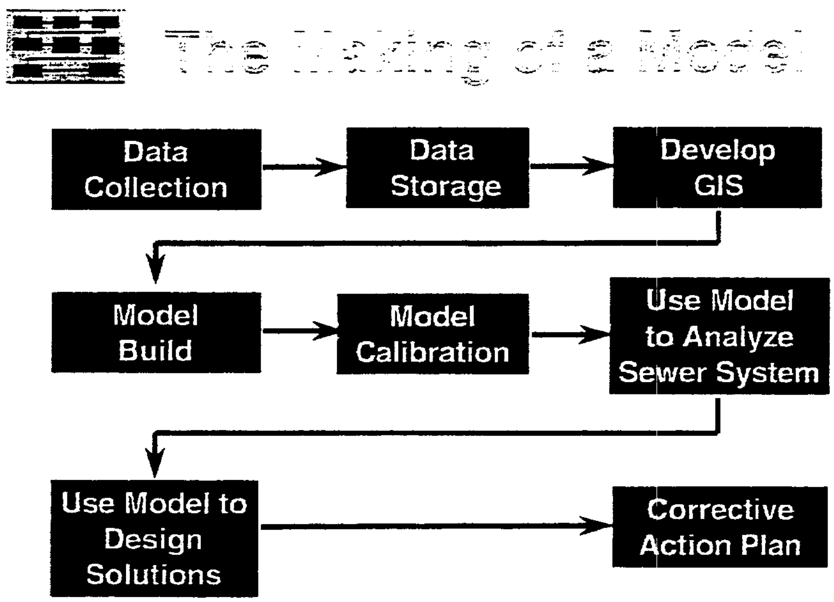

Figure 1

Following is a discussion of the data collected for use in the SSERP, its relevance to model building, and how the GIS has been utilized to store and manipulate the data.

Physical Data

The geographical configurations of both the S&WB's sanitary sewerage and water distribution systems are held on 616 paper plans on a double-line streets layout, each measuring 1-meter by 0.79-meters (42-inch by 31-inch). These plans only contain details of pipe size and location, as well as the location of manholes and water valves. Each manhole has a unique indentifier based on map sheet and manhole number. There is no information on manhole depths or rim elevations.

The S&WB uses a proprietary database system, CASS WORKS, to store details of its asset data, work activities and maintenance schedules. Within CASS WORKS there are two separate databases, one for manholes and one for pipes. The data in both of these is referenced the same as the manhole references on the paper maps. These databases contain incomplete information on street locations, ground elevations and invert levels. Also, the CASS WORKS database does not allow for the geographical display of the information.

Manhole surveying was carried out as part of the model-build task to complete missing data on pipe sizes, manhole rim elevations and pipe inverts. The X, Y and Z coordinates of each surveyed manhole was also established with the help of Global Positioning System (GPS) technology so that each manhole could be located accurately for modeling.

There are 83 pumping stations in the New Orleans sanitary sewerage system which are owned and operated by the S&WB. As part of the model build exercise, all of these pump stations were inspected and tested. Information collected included wet well sizes and pump on and off levels. Every pump was tested for a range of flow rates and delivery heads in order to obtain its current performance curve.

Data for Model Calibration

A temporary flow survey of 75 flow monitors and 20 rain gauges was carried out over an eight week period to obtain dry and wet weather flow data for model calibration. A permanent flow survey of 24 flow monitors and 10 rain gauges is ongoing.

The S&WB has recently completed the installation of a SCADA system covering all of its 83 pump stations. Data returned at regular intervals includes wet well levels at each pump station plus delivery pressure and run time for each pump.

Data for Estimating Base Sanitary Flow

Census tract boundary data was obtained in digital format. Details of the 1990 census were obtained as tables on paper and entered into the digital database of the census tracts.

Monthly water use data was obtained for each of 19,443 accounts throughout the City. For each location the water use was divided into five categories relating to the type of use (i.e., residential, industrial, etc.). The information was supplied as an electronic spreadsheet with street addresses.

Additional Data

The CASS WORKS system contained a database of 62,720 work activities which had been carried out on the sanitary sewer system since 1992. Each work activity was given a street address and the data was queried geographically. This query identified potential trouble spots in the sewerage system and was used to prioritize areas to be modeled.

GIS SYSTEM UTILIZATION

In order to store, manipulate and carry out quality assurance checks on all the collected data it was decided to use a GIS Arcview based system. The City of New Orleans was in the process of developing its own GIS system and the S&WB was working along side the City to include its data in the system. Arcview was determined to be compatible with the City's system -- an essential requirement.

The City had also completed detailed digital aerial ortho-photography of the city. These photographs were used to produce a new map of the City in GIS format which was supplied in 296 separate AutoCAD drawings. At the start of the modeling process the City's drawings contained only street lines. Some of the mapping had been enhanced to show 1-foot elevation contours and building outlines, but these features only covered part of the City's area. Both the photography and the street maps were obtained to help with displaying the sewer data geographically and to help in determining land use. To supplement the two-line street maps the paper zoning plans for the City, which contained detail down to individual housing plots, were scanned to create digital images.

A land use map produced for the City in a GIS compatible format was also obtained.

Development of the GIS system

The first step in the GIS development process was to digitize the sewer lines from the 616 paper plans. A major challenge to this task was that the plans were drawn at random orientations and did not conform to any defined grid pattern. This problem was overcome by creating scanned images of the paper plans, lining them up electronically with the 2-line GIS street map, and then tracing off the lines directly into the computer. Once this task was completed, the 616 individual units had to be combined into a single entity. Checks were carried out to confirm that all the pipes were connected and could deliver flow to the wastewater treatment plants. Finally, the digitized database of the sewer lines and manholes was cross-referenced to the CASS WORKS database and any mismatches were investigated and resolved. The pump curves for all the pumps were expressed in digital format and entered into the GIS database along with the details of wet wells and on/off levels. The location of all pump stations was highlighted geographically.

In order to geographically express the data in the water use and work activity databases, the data was geocoded. This is a GIS technique which matches a street address to a geographical location. The locations of flow monitors and rain gages, used for obtaining calibration data, was also expressed geographically in the GIS system.

The 296 separate drawings forming the 2-line street maps were combined into a few larger groupings making them more manageable. The resolution of the aerial ortho-photography was digitally reduced so that each image only was only 300Kb in size instead of the 9.8 Mb of the original. This allowed the simultaneous display of multiple photographs without over-stretching the available memory on the computers.

The scanned images of the zoning maps were scaled, rotated and positioned to line up with the 2-line street maps. Figure 2 on the following page shows the results of the digitizing efforts.

Use of the GIS in Model Building

One of the first uses of the GIS was to carry out quality assurance checks on the manhole survey data. The data was displayed geographically using the surveyed X and Y coordinates and compared to the digitized network to show any discrepancies. It was not expected that there would be a perfect match as the digitized location of the manholes was thought to be approximate, but gross differences would be investigated. Longitudinal sections were also drawn along each surveyed line using the surveyed elevation data to highlight anomalies. Figure 3 illustrates the utilization of the GIS in this quality assurance process.

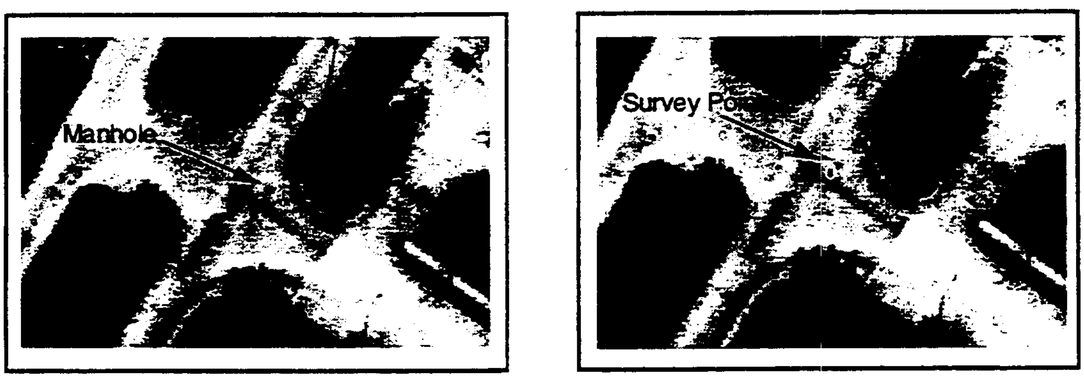

Figure 3

The aerial photo on the left indicates the location of a manhole within a street intersection. The photo on the right indicates the position of the manhole determined from the X and Y coordinates obtained in the field topographic survey. GIS enabled the model builder to check the accuracy of the survey by comparing the actual location of the manhole with that determined by survey.

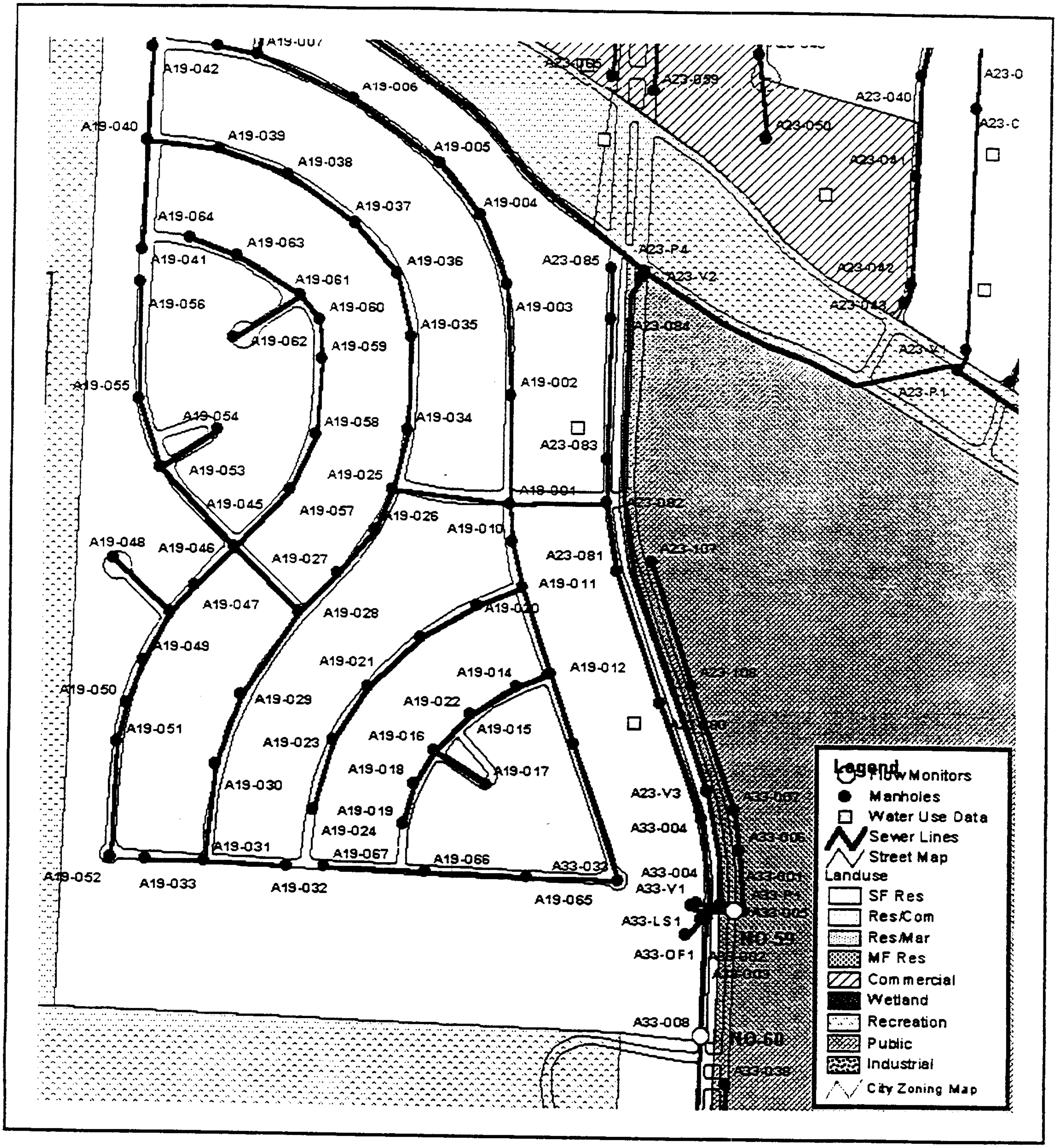

Figure 2

This is a sample of a GIS display showing the overlay of many layers of data. Displays like this allow the compilation of data for model build.

By overlaying the sewer network over the streets, land use and flow monitor data, it was possible to define model sub-basins on screen. The overlay made it possible to partition the sewer service areas logically, taking into account changes in land use and flow monitor locations. The model was to be a macro model including only pipes of 300 mm (12-inch) diameter or larger. The network feeding into each modeled manhole was defined by performing upstream traces from that point. Use of the GIS simplified the calculation of each sub-basin area. The defined areas also allowed the abstraction of population and water use data to assist with the estimation of the base sanitary flow likely to be generated. The GIS was also used to link the sub-basin to the most appropriate rain gauge for estimating run-off.

The GIS acted as a database for holding all information relative to the model. It was possible to write files compatible with the hydraulic modeling software directly from the GIS. Equally, it was possible to read model results files back into the GIS system for graphical display.

Advantages of the Use of a GIS System in Model Building

The major advantages of using a GIS system have been:

- Providing a single repository for all model data. If data requires amendment it only needs to be altered at one location, thereby maximizing efficiency and minimizing data entry errors
- The ability to display geographically and interrogate all data relevant to model building leading to a greater understanding of the system
- Geographical display allowing network connectivity to be checked easily
- Geographical display simplifying definition of sub-basins
- The GIS acts as a convenient platform for performing quality assurance checks on data
- The ability to download data directly to the model preventing data entry errors

SECONDARY BENEFIT OF GIS – REHABILITATION PRIORITIZATION PROCESS

The S&WB plans to capitalize on the GIS developed in the modeling process to help in other related planning and operational areas. One of those areas is management of the extensive library of CCTV data collected by staff and consultants conducting Collection System Evaluation Surveys (CSES) throughout the collection system service area. These surveys will collect the data necessary to identify the structural condition and sources of infiltration and inflow (I/I) in the sanitary sewer facilities in each of the ten service area basins that make up the entire S&WB managed collection system.

The CSESs involve numerous field activities such as smoke testing, dye-water testing, night flow isolation flow monitoring, manhole inspections, sub-basin flow monitoring and closed-circuit television (CCTV) inspection of sewer lines. Each study will generate approximately 72 km (45 miles) of CCTV footage, the primary tool utilized for the prioritization and method selection of sewer line rehabilitation. Because each of the ten studies will be conducted by different prime and subconsultant entities, the S&WB recognized the need to develop a centralized system that provides for consistent collection and interpretation of the CCTV data. The S&WB will utilize the GIS to help manage the storage, review and utilization of that extensive supply of system information.

The CCTV data collection system will include the following components:

- Consistent Coding of defects by field crews
- Consistent format of collected data
- Easy retrieval and review of findings due to CD-ROM indexing
- Consistent rating (grading) of defects with one S&WB standard
- Prioritization of lines for rehabilitation based on the S&WB's goal for rehabilitation (structural, I/I removal)
- Selection of cost-effective rehabilitation method for each line segment

CCTV contractors will be required to record CCTV video images in CD-ROM format. Coding will also be provided in digital format utilizing a defect coding system developed and provided by the S&WB. The coded information will be downloaded into the GIS system where defects will automatically be assigned a rating based on a predetermined grading system. The coded and rated CCTV data will then be run through a sorting process within the GIS-Arcview database that will provide for a prioritized list of sewer segments requiring rehabilitation. The sort will be based on criteria established by the S&WB to fit the goals and financial capability of the rehabilitation program.

Once the prioritized list of sewers requiring rehabilitation is generated, each sewer segment on the list will be run through a method selection decision process to determine the most cost-effective methodology to complete the rehabilitation. The method selection process will be programmed within the GIS database from decision trees. The decision process will consider all factors required to select the best methodologies including capacity needs, methodology limitations, physical pipe characteristics, surface restoration, unit costs, etc.

During the rehabilitation design process it will be necessary to review images and live video of the pipe inspections. This is where the GIS system will save time and money. With the CCTV coding residing as a layer in the GIS mapping system, and with video stored on desktop CD-ROM players, the designer can quickly access defect images with a simple 'point and click' on background system maps. The image will be displayed on screen almost instantaneously saving the time and frustration of fast-forwarding and rewinding necessary to find the sought image in the VHS format. The following Figure 4 provides a typical screen display of a CCTV image generated through the link between the line map (in background) and the video image file resident on the desktop CD-ROM.

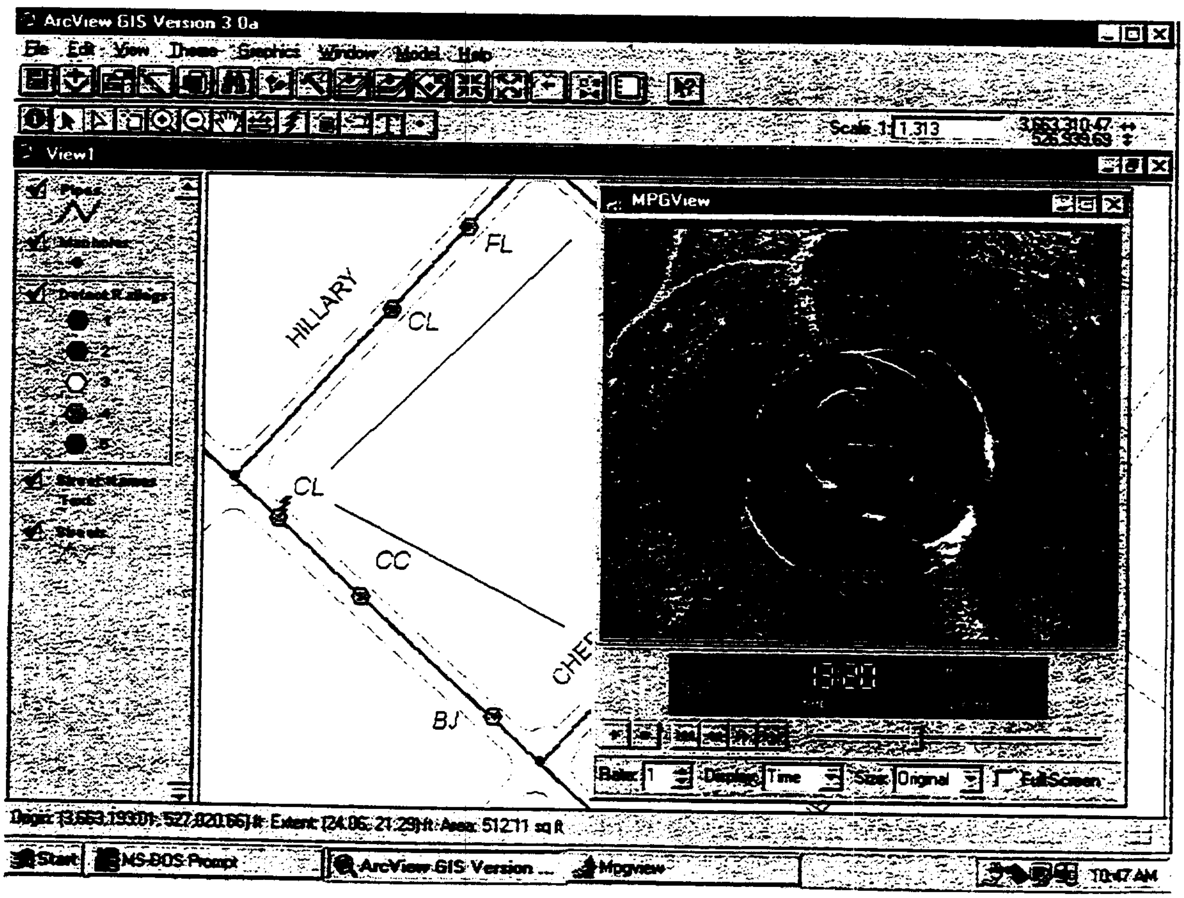

Figure 4

R0024998

Finally, the GIS system will provide the necessary mapping and graphical information required to efficiently develop maps and plans for rehabilitation construction packages.

CONCLUSION

Utilization of a GIS to collect and store the converted data in a single location not only eases the model building and calibration process, but results in secondary benefits to the operator long after the modeling phase of the project is complete. The benefits of GIS use in model building include: single location of collected data, direct download of data to populate the model, geographical display and interrogation, connectivity quality checks, and review of data before it is entered into the model.

The secondary utilization of GIS to help manage the S&WB's sewer rehabilitation is but one example of how utilities can maximize the use of GIS systems in the planning and operation of sewer and water systems. The single "one stop" geographic reference of system assets provides for quick and easy query. This can reduce emergency response times by quickly providing operations personnel with facility component locations (i.e., valves) for both the wastewater and water systems. It also provides a database to monitor operational trends, plan future work efforts and provide graphical print outs of system maps and details to assist in field reconnaissance and design activities.

In New Orleans, the S&WB system design and operations staff now have a useful infrastructure management tool that may not have been developed were it not for the need to develop the hydraulic model as part of a wet weather control program. Once in place, the full potential of GIS utilization is only limited to the imagination and a thorough understanding of its capabilities.

Wet Weather Standards and Their Role in Clean Water Act Compliance

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ABSTRACT

Today's "dry weather" water quality standards, which are designed to protect water quality during drought flow conditions, may not always be appropriate for judging the water quality impacts of stormwater and combined sewer overflows. EPA and many states have acknowledged the need to review the wet weather uses of receiving waters and, where appropriate, refine the designated uses and associated water quality standards. However, few states have taken advantage of the opportunity to conduct such wet weather designated-use reviews. There are a variety of reasons behind this, including scarce state resources and other priorities, compounded by limited state agency experience with, and understanding of, wet weather uses and criteria and their role in Clean Water Act compliance. Unless something is done to promote the review of wet weather uses, over the next decade communities throughout the United States face the prospect of spending billions of dollars to control wet weather discharges to meet water quality standards designed to protect dry weather uses. This presentation will explore this problem and offer suggestions for promoting wet weather use reviews and the development and the identification of associated water quality standards.

BOSTON WATER AND SEWER COMMISSION FINDS SEPARATION TO BE THE APPROPRIATE LEVEL OF CONTROL

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ABSTRACT

The focus of this paper is the Boston Water and Sewer Commission's efforts to reduce the adverse impacts on water quality in the Lower Charles River from the combined sewer overflows carried by the Stony Brook Conduit. During the development of its CSO Plan, the Massachusetts Water Resources Authority's proposed a screening and disinfection facility to reduce the impact of combined sewer overflows in the Charles River. The Boston Water and Sewer Commission undertook a study of alternatives to the Massachusetts Water Resources Authority's proposed facility because it believed that combined sewer overflows could be significantly reduced and possibly eliminated. The Boston Water and Sewer Commission's study recommended that all of the combined sewers along the Stony Brook Conduit be separated instead of screening and disinfecting flows at the proposed facility. After reviewing the study, the Massachusetts Water Resources Authority accepted the Boston Water and Sewer Commission's recommendation and revised its CSO Plan.

KEYWORDS

CSO Plan, Boston Water and Sewer Commission, Massachusetts Water Resources Authority

INTRODUCTION

Charles River

The Charles River begins in Hopkinton, Massachusetts, and flows in a serpentine course eastward to Boston Harbor. Visitors to Boston are familiar with the Lower Charles River Basin where the river serves as a boundary between Cambridge and Boston Massachusetts.

The Lower Charles River is primarily used for rowing and sailing. The park reservation along both banks of the river is also used for walking, jogging and gatherings. Water quality samples collected from the Lower Charles River indicate that the state's bacterial water quality standards for boating are often violated in wet weather and sometimes in dry weather. In dry weather, contamination probably comes from sanitary sewers connected to storm drains or leaking pipes that carry wastewater. Efforts are underway in Boston, Cambridge and the other communities along the river to identify and correct these conditions.

This paper will address the issues related to the wet weather conditions.

The Charles River's flows into Boston Harbor are controlled by the Charles River Dam, a flood control facility built by the U.S. Army Corps of Engineers. Contaminated flows have a significant affect on water quality in the basin.

Sources of Contamination

In wet weather, there are two major sources of combined sewer overflows (CSOs) to the Lower Charles River. They are from the Massachusetts Water Resources Authority's (Authority) Cottage Farm CSO Storage Facility on the Cambridge side of the river and from the Boston Water and Sewer Commission's (Commission) Stony Brook Conduit on the Boston side of the river.

Overflows from combined sewers along the Stony Brook Conduit can enter the Lower Charles River from two outfalls; either the Authority's CSO outfall or the Commission's, both of these are shown on Figure 1. The Authority's outfall is the primary outfall for drainage from the Commission's Stony Brook System. Although essentially all of the flow out of this outfall comes from the Commission's collection system, the outlet belongs to the Authority. During very severe storms, the Commission's CSO outfall serves as another way for CSOs to enter the Lower Charles River. When flows in the Stony Brook Conduit overtop the sluice gates at the Commission's outfall, they enter the Muddy River. The Muddy River flows into the Lower Charles River near the Authority's outfall.

DISCUSSION

The Authority's CSO Plan for the Stony Brook Conduit

The Authority evaluated various methods for reducing the impact of CSOs on the Charles River. They looked at storing overflows until capacity was available at the treatment plant. Storing overflows from a large storm event such as the 1-year storm was rejected by the Authority because it would be difficult to find enough area for the storage tanks.

The Authority also considered diverting some of the overflows caused by a three-month storm into an interceptor with excess capacity (the Commission's Stony Brook Valley Sewer), and storing the overflows from the rest of the combined areas in a storage tank. Although the area needed for storage was less, this alternative was also rejected. The improvement in water quality did not justify the cost of the storage tanks and the diversion.

As another possibility, the Authority investigated separating sanitary and stormwater, but concluded that separation was too difficult and too costly since most of the combined sewers are in highly developed urban areas.

Finally, the Authority investigated and ultimately recommended that the combined flows in the Stony Brook Conduit be screened and disinfected before being discharged to the Charles River. A screening and disinfection facility was proposed, located near the end of the conduit, because overflows occur along this downstream portion of the conduit.

Along much of its length, the Stony Brook Conduit serves areas with separate storm drains. About 2,533 hectacres (6,260 acres) contribute separate stormwater flows to the upstream portions of the conduit (see Figure 1). Along the downstream sections, about 617 hectacres (1,524 acres) contain combined sewers. Overflows from combined sewers contribute a relatively small percentage of the wet weather flows carried by the conduit.

According to the Authority's computer model, the facility would be activated about 26 times in a "typical year". During these events, about 2.328 million cubic meters (615 million gallons) of stormwater plus CSOs would be treated at the proposed facility. A "typical year" is a group of rain events developed by the Authority that provides a way measuring performance on an annual basis.

When the facility screens and disinfects, most of the flow would be stormwater. Only 155,185 cubic meters (41 million gallons) or 7 percent of this volume actually comes from CSOs; the rest is stormwater and brookflow from four brooks upstream that discharge into the Stony Brook Conduit.

On average, about 80 rain events occur each year. If the rainfall is not large enough to cause overflows, the proposed facility would not be activated. During the smaller rain events, about 54 times a year, stormwater would be discharged into the Charles River without any screening or disinfection.

Commission Concerns

Based on its knowledge of the Stony Brook sewer system, the Commission believed that more alternatives should be evaluated before giving its support to a screening and disinfection facility. Alternatives closer to the source of overflows needed to be investigated so that less stormwater would be handled. If overflows could be reduced further upstream rather than near the end of the pipe, then it should cost less to reduce CSOs.

The Authority's proposed facility was to be located near the end of the pipe which would result in a significant amount of stormwater being treated whenever the facility activated. Over the life of the facility, most of its operating expenses would be due to treating stormwater, not CSOs.

The Commission recognized that stormwater also adversely affects water quality. Screening and disinfecting, however, reduces bacteria and solids, but not the other pollutants found in stormwater. The Commission questioned whether screening and disinfecting would be the appropriate level of treatment for stormwater.

In addition to the concerns about how effectively the facility would reduce the impacts of CSOs, several issues surfaced that created other reservations about the constructing a facility.

The Commission realized that there was not a consensus on the water quality goals for the Charles River among citizen groups and the Authority. The citizens clearly supported fishable and swimmable waters in the Charles River at all times. If the facility could not prevent CSOs it might only be an interim measure and not a long-term control.

Most of the vacant lands along the downstream portion of the Stony Brook Conduit are either used or designated for use by one of the institutions that are located in this section of Boston. The Authority encountered significant resistance from the local neighborhood associations, colleges and the city's housing authority about siting a screening and disinfection facility in this area.

Additionally, since chlorine was to be used for disinfecting the flows from the Stony Brook Conduit, the Authority would be required to dechlorinate the flows before they reach the Charles River. It appeared likely that the Authority would encounter problems finding an additional location to dechlorinate the flow.

The Commission's Stony Brook Sewer System Study

After reviewing the Authority's plan to reduce and treat CSOs from the Stony Brook Conduit, the Commission undertook its own study to find an alternative to the Authority's proposed facility. The Commission did not wish to duplicate efforts, but to address issues raised during the review of the Authority's plan.

The Commission believed that controls such as separation and storage, should be re-examined and studied in greater depth before building a costly and unpopular screening and disinfection facility. Even if an alternative to the proposed facility was not found, the Commission hoped that the study could identify ways to reduce the size of the screening and disinfection facility, the number of times it was activated and therefore its cost.

The Commission's study looked for controls in each sub-area where combined sewers overflow into the Stony Brook Conduit. Controls were evaluated based on their ability to reduce CSOs to four times a year or less.

Under the U.S. Environmental Protection Agency's 1994 National CSO Policy, CSO controls and compliance with water quality standards can be developed using either the presumption approach or the demonstration approach. For this study, the Commission used the presumption approach where it assumed that if no more than four overflow events per year occurred, water quality standards would be met.

Alternatives examined

To reduce overflows to less than four times a year, the Commission looked at:

- separating sanitary and stormwater flows,
- storing overflows,
- enlarging the connection at each regulator
- diverting overflows into other sewers.

In each sub-area, the study examined separating flows from a portion of the combined sewer area rather than the entire area. The area to be separated would need to be just large enough to reduce overflows to four times a year or less. Before making these calculations, it appeared that separating a portion of the combined sewer area could reduce overflows significantly and would cost less than complete separation. However, the calculations showed that almost the entire area needed to be separated to reduce overflows to four times a year or less.

The study evaluated two types of storage alternatives, one used existing sewers and the other proposed the construction of new facilities. The first alternative looked at whether overflows could be stored within existing pipes in the Stony Brook System. It was quickly determined that the existing sewers were not large enough. Then the study looked at building storage close to where the overflows occur. This alternative was dropped because siting and operating storage facilities in several sub-areas presented too many insolvable issues.

Enlarging the connection from the regulator to the interceptor was examined, because it would increase the amount of wet weather flow that stayed within the collection system, resulting in less overflows. The reduction in overflows, estimated by the Commission's computer model was not significant at most of the regulators. At two regulators, it appeared that reductions could be achieved, but more detailed investigations were needed to determine whether enlarging the connections was feasible.

Diverting overflows into a sewer that was able to direct the flows to the treatment plant was also examined. The Stony Brook System is a complex network of interceptors and outfall pipes. Using the Commission's model, overflows were routed into an interceptor with excess capacity. The model's results indicate that it would be possible to divert overflows from a three-month storm into an interceptor where the flow would be conveyed to the Authority's treatment plant.

Findings

After evaluating the alternatives, the Commission's Study found the following:

- It is possible to use a combination of methods such as separation, diverting overflows, and enlarging connections to reduce overflows to four times a year or less.

- The largest reduction in the frequency of CSOs occurs when all of the tributary areas are completely separated. According to the Authority's hydraulic model, overflows will occur about two times in a "typical year".

- Separation removes pollutants, such as total suspended solids and biochemical oxygen demand, that would not be removed by a screening and disinfection facility.

- Complete separation of the combined sewer areas tributary to the Stony Brook Conduit costs about $ 6 million less than the screening and disinfection facility

- However, separation increases the amount of stormwater discharged into the Charles River, which raises the concern about the effect on water quality from this additional flow.

Recommendation

The Commission's study recommended the complete separation of the combined areas tributary to the Stony Brook Conduit as well as the control of floatable materials, if overflows still occur in a "typical year".

To make sure the water quality of the stormwater will not further degrade the water quality in the receiving water; the Commission's study also recommended :

- best management practices, such as cleaning catch basins and public education programs on the proper disposal of motor oils and pet wastes,
- the removal of illegal connections in all the already separated areas, and
- the rehabilitation of existing sanitary sewers in common trenches

Authority Revises its CSO Plan

Shortly after the Commission's study was completed, the Authority reviewed the study, analyzing the separation recommendation with its computer model. It agreed that complete separation of the areas tributary to the Stony Brook Conduit was an attractive solution, because it provides a higher level of control than a screening and disinfection facility. Several citizens' groups concerned about water quality in the Charles River had urged the Authority to provide a higher level of control than the screening and disinfection during the review of the Draft CSO Facilities Plan.

After deciding to adopt separation for the Stony Brook System, the Authority offered to reimburse the Commission up to $ 45 million for constructing of a separate system in the combined areas tributary to the Stony Brook Conduit. The Commission readily accepted the cost ceiling and responsibility for this project.

When the Final CSO Facilities Plan/Environmental Impact Report was issued in July of 1997, the Authority changed its recommendation from a screening and disinfection facility to the complete separation of the areas tributary to the Stony Brook Conduit. The Authority appears to have made this change because of difficulty in siting the facility, the increase in the cost of the CSO facility and concerns about water quality from several citizens organizations. The selected site presented concerns about the pipes into and out of the proposed facility would be constructed. The cost estimate for the proposed facility was higher than the estimate in the Draft CSO Facilities Plan because the Authority discovered that it was necessary to dechlorinate the flows. It was also attractive that the Commission would be responsible for implementing separation and operating the separate systems whereas the Authority would have been responsible for operating the CSO facility.

RESULTS

Authority and the Commission enter into an agreement

Under the Final CSO Plan, the Authority will implement most of the other improvements such as interceptor relief, storage, a treatment facility, upgrade of existing CSO facilities and the relocation of CSOs. The Commission has already undertaken two separation projects within the city of Boston; the Stony Brook Conduit project will be its third CSO separation project.

In May of 1994, the Commission entered into an agreement with the Authority for the separation of combined sewer areas in Dorchester and in East Boston. This agreement defined the responsibilities of each agency. These separation projects were given priority because overflows in these areas discharge into Boston Harbor near waters used for bathing.

The Authority's CSO Plan was developed under a Court Order. The Court oversees the implementation of the plan. The Commission is responsible for completing the separation, according to a schedule set up by the Court. In turn, the Authority will reimburse the Commission for the design and construction costs associated with separation.

The Commission has completed the preliminary design for the Dorchester separation. According to the preliminary design about 130,000 linear feet of storm drains will be installed in Dorchester to separate its combined sewer areas. By comparison, complete separation complete separation of the areas tributary to the Stony Brook Conduit will require as a very rough estimate, about 100,000 linear feet of pipe.

Both the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection support the Authority's recommendation to completely separate the areas tributary to the Stony Brook Conduit. Later this year, the EPA and the Authority will submit a schedule for the implementation of the CSO Plan to the Court for their approval. When the Court schedule is available, the agreement between the Authority and the Commission will be amended to include the separation of the areas tributary to the Stony Brook Conduit.

From the Boston side, CSOs from the two outfalls into the Charles River will be reduced to two or less a year by 2005.

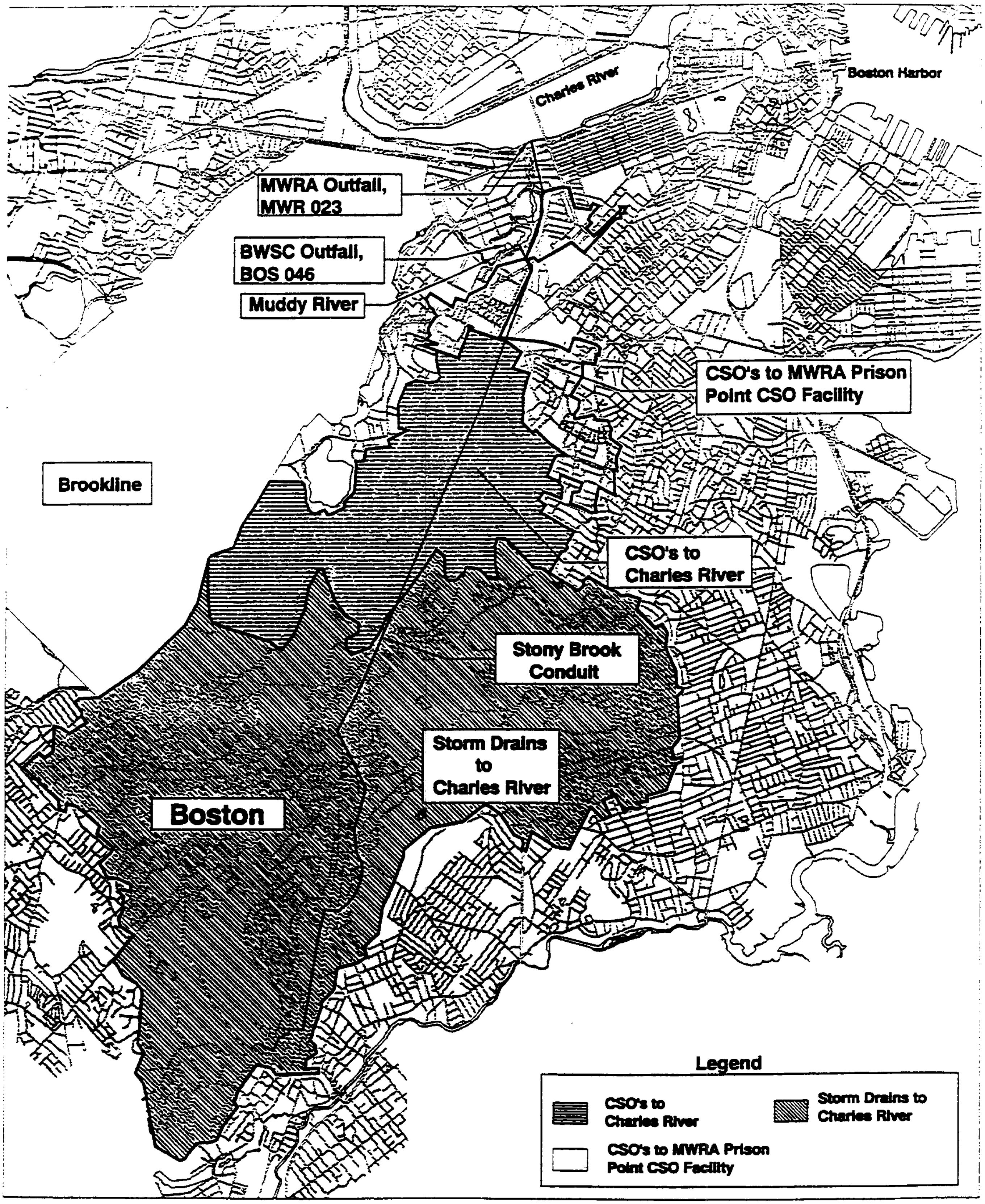

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Figure 1
Drainage Areas In The Stony Brook System

CONSTRUCTED WETLANDS BALANCE URBAN WET WEATHER CHALLENGES

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ABSTRACT

Urban Planners and Engineers often face conflicting goals when dealing with urban storm water runoff: flood reduction, water quality enhancement, and habitat enhancement or preservation. This paper demonstrates the multiple advantages that constructed wetlands can offer to balance these challenges.

Creatively designed storm water wetlands can serve multiple purposes, be an attractive community asset, and provide ecological as well as economic benefits. Potential benefits of constructed wetlands include replacement of impacted wetlands, storm water management, storm water purification, reducing combined sewer overflows, parks and open space, scenic enhancement, an outdoor learning laboratory, and wildlife habitat. These additional benefits can be optimized by incorporating constructed wetlands into the design of a variety of project types and settings such as land development, parks or school projects.

Many cities and counties today face flood control, water quality, or open space issues with limited funds to address such issues. Constructed wetlands can offer cost-effective solutions to such issues. The zoning or wetland permitting process can in fact produce replacement wetland projects which fulfill community needs at no cost to the City.

Land developers can realize the economic benefits of incorporating constructed wetlands into their developments thru the added value to surrounding residential lots; through the creation of a low cost, low maintenance open space amenities; and by providing potential additional revenue from the sale of mitigation credits.

Three case studies are presented which demonstrate constructed wetlands in a range of settings:

- the Wetland Conservation Area: located in New Albany, Ohio; combining wetland mitigation, storm water management, and educational use in a 30-acre wetland park.
- the Streetsboro Wetland Park: located in Streetsboro, Ohio, combining wetland preservation, wetland mitigation, and flood control in a 58 acre open space development amenity and city park.
- the Oakland Ravine Wetland Treatment System: located in the Borough of Queens, New York City, combining CSO reduction, storm water treatment, park enhancement, and educational use.

KEYWORDS

Constructed wetlands, wetland mitigation.

INTRODUCTION

Urban planners and engineers often face quite a number of challenges when addressing urban storm water issues: flooding, erosion, wetland preservation, habitat restoration, and water quality. Urban stormwater may also be related to other urban issues such as parks and open space, park funding, property values and economic development.

Creative planning and design can produce constructed wetland projects which successfully balance ecological, economic, engineering and aesthetic values. Constructed wetlands can be successfully incorporated into a variety of suburban and urban settings such as parks, schools, commercial and industrial landscapes. Wetland preservation and wetland replacement can also be a funding tool for open space preservation or parkland acquisition. A growing body of literature is available on the engineering aspects of constructed wetlands such as stormwater management, pollutant treatment and water quality improvement; however, not much literature exists on other wetland benefits such as economic development and scenic enhancement.

METHODOLOGY

Three constructed wetland project case studies are presented to illustrate how to balance multiple challenges with creative planning and design techniques. These projects will demonstrate the multiple advantages that constructed wetlands can offer such as:

- provide replacement wetlands, fulfill regulatory requirements for wetland impacts,
- creation or enhancement of parks and open space,
- stormwater management, by reducing peak runoff rates by providing stormwater storage,
- reduction of flood damage and enhanced economic development,
- water quality improvement, water filtration pollutant reduction,
- restoration of watershed habitat, increase wildlife diversity,
- scenic enhancement,
- increase the value of surrounding real estate,
- reduction of runoff volume by providing increased soil infiltration, evaporation and transpiration,
- provide a setting for environmental education.

RESULTS

The Wetland Conservation Area (WCA) is located Northeast of Columbus, Ohio, in New Albany, Ohio, south of SR 161. The WCA is the first significant sized wetland mitigation project undertaken by the Ohio Department of Transportation (ODOT) and is a landmark project in Ohio in demonstrating that wetland mitigation can be an integral, multipurpose element in land planning and may even be planned as a centerpiece to surrounding development.

Project goals were to replace wetlands impacted by an adjacent highway project. The project represents a very successful public/private partnership between ODOT and the developer, the New Albany Company, and the Village of New Albany, in conjunction with the New Albany School District. A unique 'win-win-win' situation developed where ODOT fulfilled its regulatory needs; the Developer got a theme element, a stormwater basin, and increased land values; the Village and Schools got a new park and land lab valued at $2 million, at no cost to the Village.

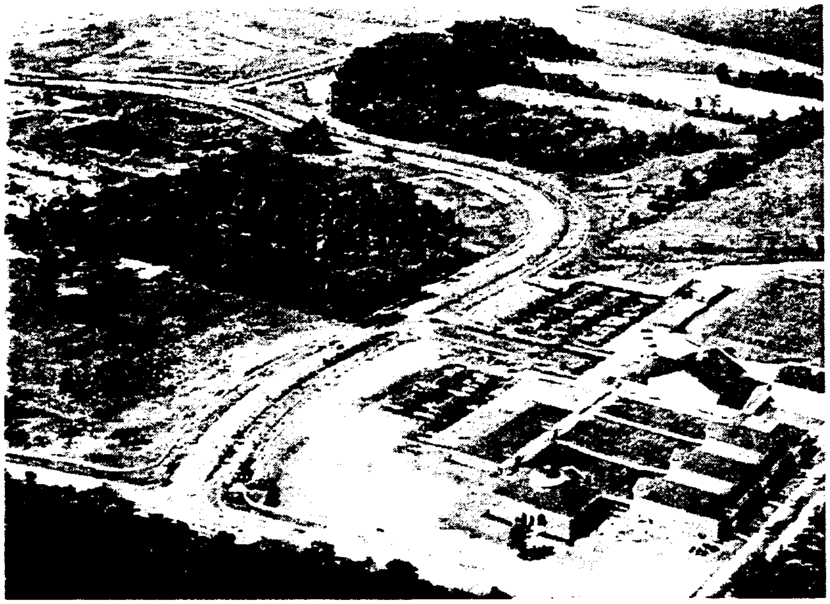

Figure 1. This aerial photo provides an overview of the WCA's surroundings: deliberately located at the primary expressway interchange entrance to a new 5,000 acre community. This location produces a high visibility open space area that establishes a strong natural theme for the New Albany community. Commercial, residential, school development, roads and trails have been designed around all sides of the WCA.

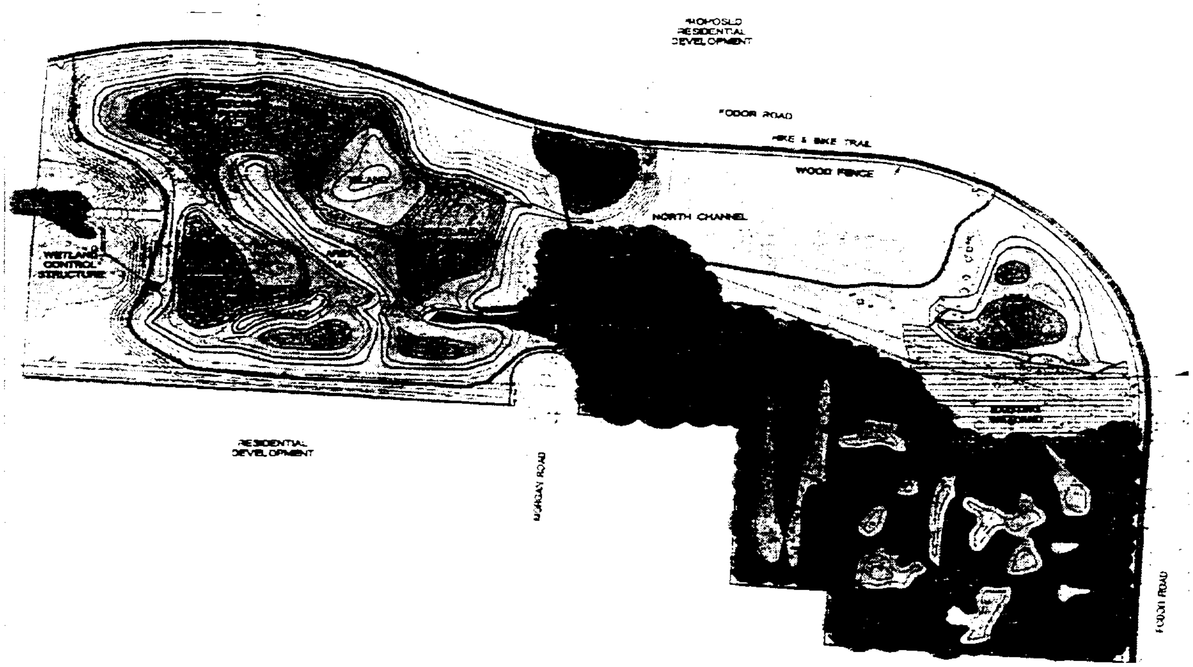

Figure 2. This plan view illustrates a number of basic design features of stormwater wetlands such as a forebay for sediment trapping, and a circuitous flow pattern to enhance pollutant reduction effects. The park provides a total stormwater storage area of more than 13 acres, dramatically reducing peak discharge rates significantly below code requirements. The control structure is the result of extensive hydrologic modeling to analyze stormwater management functions, as well as water balance modeling to document the viability of the constructed wetlands. These software analyses resulted in the design of a unique three stage control structure to enhance wetland hydrology during low flows, provide complete adjustability of discharge rates and water levels, and accommodate peak flows from the ultimate build out of the watershed.

Figure 3. Constructed wetlands can be successfully established in urbanized surroundings. The naturalized open space area is considered a desirable neighbor. It is reported that homes adjacent to the WCA are selling for $10,000-$15,000 more than homes across the street. Shallow water depths, gentle slopes, and moderate water level fluctuations are compatible with public access and in fact pose far less public safety issues than ponds or retention basins.

Figure 4. Wetland vegetation is most diverse, successful and beautiful in water depths of 0-6 inches. This diversity of form, texture, color, and height creates a visually rich landscape. From an ecological design perspective, one of the project's most unique aspects is the design of three distinct ecological zones, open emergent, emergent and forested vernal pools, a unique combination in a constructed wetland project.

Figure 5. The vernal pool area is perhaps the most unique ecological zone in the project. A number of small, organically shaped and randomly placed pools were designed in an existing wet woods area to mimic natural vernal pools. The wooded wetland areas not only add to the site's flood storage capacity but also provide a fascinating laboratory for the study of how each pool is being colonized by different species of frogs and salamanders. A number of adjacent schools and colleges have visited this area for biological study. Forested vernal pools are considerd one of the highest quality wetlands in the Ohio EPA classification system.

The WCA project earned an Honor Award in 1997 from the Ohio Chapter of the American Society of Landscape Architects.

The Wilcox Wetland Park is located in Streetsboro Ohio, on the eastern fringe of the Cleveland metropolitan area, between SR 303 and SR 14. Project goals were to develop a plan which integrated wetland preservation, wetland mitigation and stormwater management for a 200 acre mixed use development including residential, industrial, and commercial uses. The plan incorporated the preservation of approximately 20 acres of existing wetlands and a stream corridor, enlarged existing wetlands by an additional 12 acres, solved chronic flooding of SR 303, provided stormwater management for the project, all within a 56-acre central open space amenity. Presentation of this plan to City Council was instrumental to gaining rezoning for a critical piece of the property. The rezoning issue was headed for denial; presentation of the open space plan resulted in unanimous passage and praise as a prototype for an environmentally sensitive project.

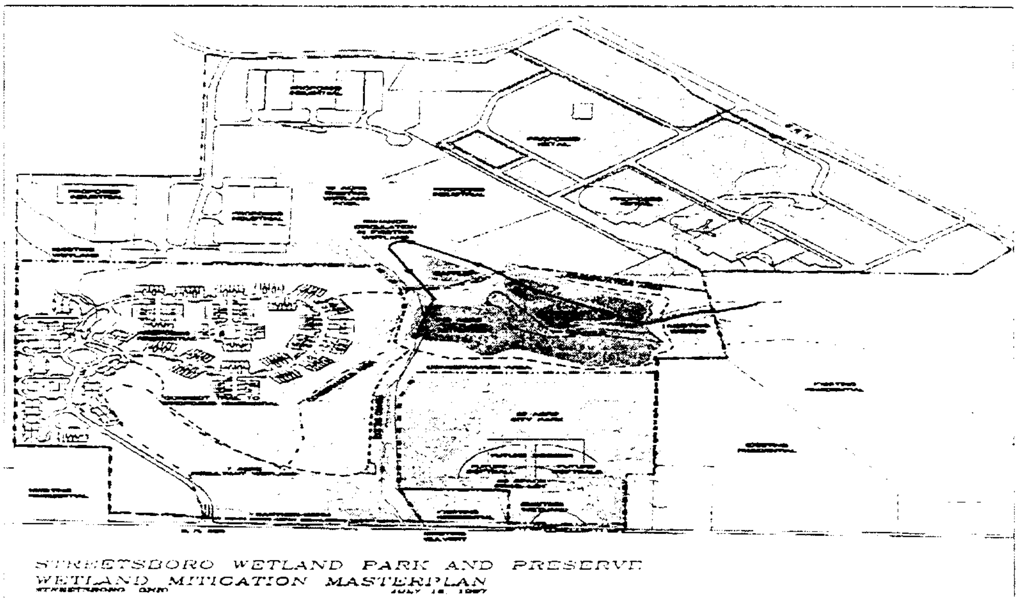

Figure 6. A plan was developed to integrate the preservation of existing wetlands, construction of new wetlands, a proposed 22 acre park to be donated to the city. The plan will eliminate chronic flooding of a state highway, and provide a huge stormwater storage facility of more than 35 acres of storage area to significantly reduce flows and volume. The result represents a successful 'win-win' between private development and public benefits.

Figure 7. The combination of existing wetlands and replacement wetlands will create an extraordinarily large central open space amenity to this mixed use project. This open space reduces the overall density of the proposed residential development and builds upon the scenic character of the surrounding landscape.

Figure 8. Native herbaceous wetland vegetation can add a unique visual character to urbanized settings; adding textures, unusual forms, lushness, and subtle shades of green, not seen in typical landscapes. These naturalized landscapes require little or no maintenance.

The Oakland Ravine Stormwater Wetland Treatment System is located in the Borough of Queens, New York City, adjacent to Alley Creek Park. This project illustrates that constructed wetlands can be designed into even highly urbanized settings. Oakland Ravine is a landmark project in New York City, designed to reduce combined sewer overflows (CSOs) and provide stormwater treatment. This project will be presented in greater detail in a subsequent paper.

Figure 9. Oakland Lake, the receiving body for treatment wetland flows, is a heavily used recreational lake in the New York City Park system. Project design goals were to reduce CSOs by disconnecting a storm sewer from the combined system and route the discharge through a 2.5 acre treatment wetland for filtration prior to entering a recreational lake. Multiple other design goals include stabilization of severely eroded ravine slopes, stormwater management of the adjacent area, ecological restoration, park access, public education.

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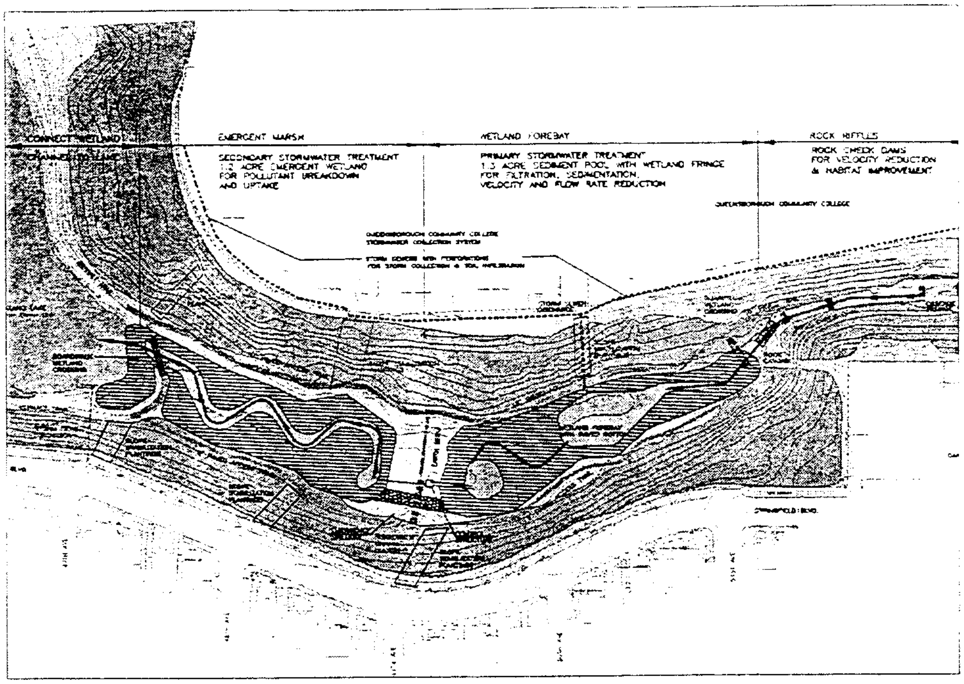

Figure 10. The site is surrounded on all sides by a community college, a grade school, and dense residential neighborhoods. This location will provide an educational resource to the three adjacent schools. A number of design elements, such as a paved sediment forebay were included to minimize maintenance operations. The stormwater treatment wetland is projected to reduce most pollutants by 50-75%. The Preliminary Plan has achieved an interagency consensus between two city departments, the Department of Environmental Protection (DEP) and the Department of Parks and Recreation (DPR).

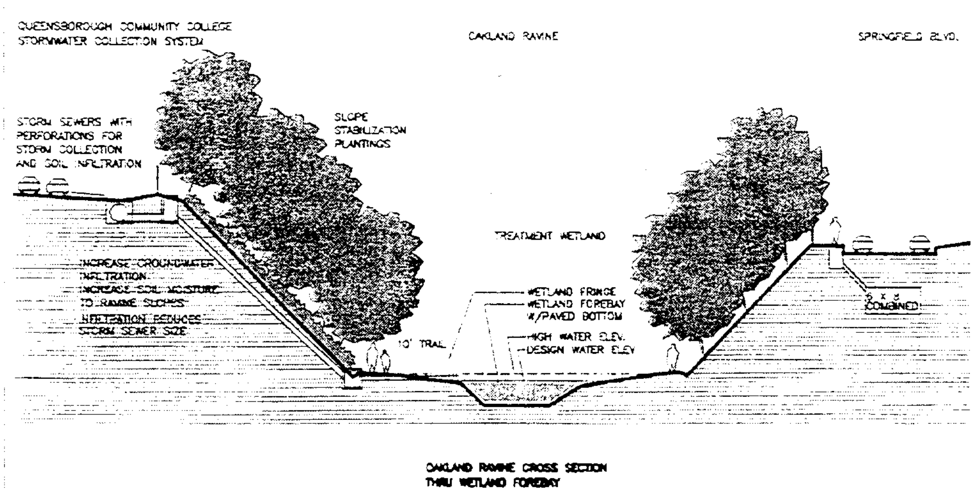

Figure 11. Oakland Ravine slopes are 60-80 feet in height, heavily wooded, and severely eroded at a number of locations. A primary design goal was to develop a naturalized design character for all hydraulic structures such as headwalls, energy dissipaters, channel protection, and control structures. This naturalized design character will provide scenic enhancement of the park and take the form of rock cascades, plunge pools, restored stream channel, and planted gabions.

DISCUSSION

The evolution of wetland protection regulations is an expression of society's growing recognition of the services wetlands provide. Current regulations require each project to demonstrate avoidance and minimization of impacts to existing wetlands. Small impacts may be permitted and mitigated with relative simplicity. Larger impacts may require a thorough documentation of project alternatives to convincingly demonstrate the unavoidable need for wetland impact. Unavoidable impacts may be replaced or mitigated either onsite or offsite according to a replacement ratio tailored to each project. Both Federal and State wetland regulations are growing more protective. In May, the Ohio EPA implemented water quality regulations implementing a wetland classification system which effectively increases the wetland replacement ratios required for wetland impacts. Impacts to wetlands classified as high quality require higher ratios of wetland replacement. These regulations make wetlands a major factor in the land planning equation. In many parts of the country, it is virtually impossible for any major infrastructure or land development project to avoid wetland impacts.

Watershed planners should be prepared to take advantage of mitigation opportunities for watershed restoration purposes. An integrated mitigation strategy which incorporates wetland preservation, wetland mitigation and stormwater management can provide higher levels of wetland functions and values than the wetlands impacted. Offsite wetland mitigation can provide a funding vehicle to address urban watershed restoration by creating opportunities for public/private partnerships. Larger wetland mitigation areas can be permitted to form "Wetland Banks" to cost effectively provide for present and future wetland impacts. Many park districts have created wetland mitigation banks to advantage of these opportunities and capture additional revenues for wetland projects.

The integration of wetland preservation, mitigation wetlands and stormwater management functions requires both careful design and close coordination with regulatory agencies. Erosive flow velocities, sediment deposition and large water level fluctuations can threaten the establishment of a healthy and diverse wetland community. Constructed wetlands can be engineered to provide stormwater retention using many of the same modeling techniques used for retention basins, such as TR-55 and HEC-RAS. However few, if any regulatory agencies will approve mitigation credit for retention basins. Successful integration may require a number of design techniques such as enhancement of existing wetlands, storm sewers discharging to pretreatment pools, and hydrologic modeling to document non damaging flow velocities and water levels. Projects which successfully integrate on site wetland preservation, wetland mitigation and stormwater management usually result in storage areas significantly larger than a traditional retention basin; a key factor for moderating water level fluctuations.

One shortcoming of most stormwater management codes is increased runoff volume. Retention basins can effectively reduce peak rate discharges from proposed developments, nonetheless, more impervious surfaces mean flood peaks for longer durations. The large storage area of wetlands can reduce runoff volumes through several methods: soil infiltration, evaporation, and plant transpiration. The degree of volume reduction can be modeled with water balance equations or software to determine the volume reduction effects of each project.

Wetlands have been described as nature's kidneys. Stormwater treatment wetlands provide both physical and biological processes for pollutant removal. Sedimentation is usually the predominant pollutant removal mechanism, using gravity to remove suspended solids. The abundance of water in wetlands makes them the most biologically productive ecosystems in North America. This high rate of biological activity provides wetlands with the ability to transform many common pollutants into harmless by-products or essential nutrients.

A sizeable body of scientific and governmental publications have documented treatment wetlands as a proven technology for the improvement of surface water quality. Stormwater wetland treatment systems use both physical and biological processes for pollutant removal. Sedimentation and filtration of floatables are usually the predominant physical pollutant removal mechanism. Adsorption of pollutants onto the surface of sediments, vegetation and organic matter is a principal mechanism for removal of dissolved or floating pollutants. Biological processes consist of pollutant digestion by bacterial action, decomposition of organic matter, and nutrient uptake by wetland plants. Published results on wetlands' ability to remove pollutants from stormwater indicate that total suspended solids and selected nutrients and metals may generally be reduced by 50-75%. Removal efficiencies may be affected by a variety of factors such as wetland sizing, seasonality, hydraulic conditions, climate, and reporting procedures (Strecker 1996). Numerous wetland treatment systems are already in place across the country, efficiently improving water quality in agricultural, mining, industrial and wastewater treatment applications.

Careful design of constructed wetlands can serve both hydraulic functions and produce a rich and diverse wildlife habitat. Irregular shoreline configurations, small islands, and small pools provide a variety of habitat niches for waterfowl, shorebirds, songbirds, amphibians, aquatic insects. Wetland complexity helps to avoid undesirable wildlife scenarios such as the 'goose pond syndrome' common to parks and golf courses containing ponds adjacent to grass areas. Such settings can develop a year round population of ducks and geese which will consume large volumes of wetland plants and leave vast quantities of droppings which raise nutrient levels in ponds. Perhaps the greatest fear about stormwater wetlands is that they will become infested with swarms of mosquitoes. In reality, mosquito problems have been seldom encountered with stormwater wetlands (Schueler 1992). A design which avoids stagnant water areas with adequate hydrologic flushing is one design strategy. Mosquitoes are part of a food chain which includes mosquito predators such as frogs, toads, salamanders, dragonflies, purple martins, and bats. Bats are the single most effective mosquito predator, consuming up to one half their body weight in a 24-hour period.

Constructed wetlands can produce significant scenic enhancement benefits. A diverse wetland plant community can create a rich visual variety of shapes, textures, patterns, colors; in sharp contrast to the typical lawn and pond landscapes found in many parks and commercial landscapes. Many wetland plants produce colorful flowers and can be designed into the aquatic landscape like an impressionist painting. The winter wetland scene can contain a variety of plant heights and textures and resemble a large dried floral arrangement. Creative design of hydrologic features such as open water, small islands, small pools and naturalized stream channels add further visual drama.

Incorporation of constructed wetlands and stormwater functions into urban parks is not a new idea. In the late 19th century Frederick Law Olmsted, the father of the Landscape Architecture profession, designed several large urban parks which successfully combined stormwater features, water reservoirs and the creation of natural scenery in well known urban parks such as Central Park and Prospect Park in New York and Fenway Park in Boston. The restorative powers of natural scenery to delight the eye and refresh the spirit was one of Olmsted's fundamental design goals (Beveridge 1995). The psychological value of natural scenery in urban areas is under appreciated, overlooked, or trivialized in contemporary park design.

Constructed wetlands may also be planned to produce a number of powerful economic effects. Land use in planned developments may be optimized by integrating wetland preservation, constructed wetlands, and stormwater management, into an open space amenity. Studies of open space have found property value increases of 7-23%, where property faced open space (Weich and Zeibst 1973). Increased property values are beneficial to both the public and private sectors, in increased tax rolls and higher revenues from land sales. Stormwater management becomes an economic development issue when chronic flooding creates community disinvestment. Identification of strategic stormwater projects to solve these chronic flooding conditions can encourage reinvestment in formerly blighted areas.

Constructed wetlands adjacent to schools can be an exciting addition to the curriculum of all ages. As an outdoor land they can provide hands on experiences to students and make curriculums more relevant in variety of subjects such as math, biology, chemistry, ecology, art, and English.

CONCLUSIONS

These case studies illustrate that skillfully designed constructed wetland projects can balance multiple challenges; fulfill ecological and engineering criteria, be aesthetic and enhance economic development. Such projects can be a vehicle for the restoration of degraded urban watersheds and represent a tool for communities to show compliance with the upcoming Phase II NPDES regulations to be implemented in March 1999.

Stormwater wetlands can be constructed for the relatively low cost of earthwork, simple hydraulic structures, and plantings. Operation and maintenance costs are also relatively low due to the utilization of natural energies of the sun, plants, soil, and animals. No fossil fuels or chemicals are necessary for the operation of stormwater wetland treatment systems. Stormwater wetlands may be constructed at costs ranging from $10,000-$40,000 per acre depending on earthwork requirements and site amenities.

A multi discipline design team is fundamental to fully realize the multiple benefits of such projects. The projects presented are the result of a multi discipline collaboration of Landscape Architects, Hydraulic Engineers, Wetland Scientists, Permit specialists, and Geotechnical Engineers. Each discipline brings to the table unique skills necessary for a successful project: watershed hydrology, hydrologic modeling, soils engineering, plant communities' identification, ecological restoration, regulatory compliance, as well as skills in land planning, park design, grading, and landscape design.

Throughout the Great Lakes Basin, 43 Remedial Action Plans (RAPs) are in operation, formulating strategies to improve water quality and enhance habitat. The Washington, D.C. metropolitan area has implemented numerous stormwater wetland projects as a means of improving water quality in Chesapeake Bay. One may envision metropolitan areas throughout the Great Lakes region planning an array stormwater wetland parks throughout their urban watersheds to solve wet weather challenges and address other community issues. Such projects could provide significant public benefits and be partially funded by private sector wetland mitigation requirements. Many urban areas contain numerous candidate sites waiting for such projects, such as parks with damaged water features, degraded flood plains, abandoned quarries, leftover commercial or industrial sites, or damaged municipal detention basins, that may be creatively reconfigured to provide an attractive asset to the watershed and the community.

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IN-LINE STORAGE WITH AND WITHOUT REAL TIME CONTROL

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ABSTRACT

The City of Winnipeg initiated a major Combined Sewer Overflow (CSO) Management study in 1994 to "establish a cost-effective prioritized implementation plan for remedial works based on assessment of costs and benefits of practicable alternatives". Results from phase 3 of the 4-phase study strongly indicate that use of available in-line storage in the 43 individual combined sewer districts (total area about 10,000 ha) is the most effective and logical first step in the emerging wet weather pollution control plan. A "demonstration approach" was used to assess whether or not a proposed control plan could effectively achieve specific water quality objectives. As well, it was deemed important to asses options that were consistent with the EPA "presumptive approach" goals of 4 overflows and 85% capture.

A detailed review of Winnipeg's combined sewer systems confirmed that the volume of available in-line storage was substantial but unevenly distributed. Planning level models were developed to assess the use of existing in-line storage, identify strategic locations for additional storage/district transfers, optimize dewatering and conveyance rates, evaluate wastewater treatment plant limitation/upgrade requirements, and assess receiving stream water quality improvements. Real-time control and non-RTC strategies were evaluated to identify practicable control options which could maximize the use of available in-line storage without increasing the risk of basement flooding. It was found that strategies involving local RTC were less costly and could fully utilize available storage but contained a small element of risk. A non-RTC option involving "finger" weirs was found to be effective, contained no risk, but could not fully utilize storage.

This paper will present the analyses and the description of trade-offs between cost, risk, and performance measures of the range of storage options.

KEYWORDS

combined sewer overflows, in-line storage, real time control

INTRODUCTION

Winnipeg is the capital city of the Province of Manitoba, Canada, and is situated on the confluence of two major rivers, the Red and the Assiniboine rivers. Winnipeg's current population is about 650,000 and comprises a developed area of about 28,000 ha. The older central portion of the City is about 10,000 ha in size, and is serviced by a combined sewer system. The combined sewer serviced area is divided into 43 combined sewer districts, each of which overflow from 7 to 37 times during the recreation season (May to September, inclusive). During dry weather, the flow is diverted into interceptors and brought to three water pollution control centers (WPCCs) for complete secondary treatment. Plans are underway to disinfect the dry weather effluent from one of the treatment plants and the other two plants are under study.

The City is currently working on a combined sewer overflow (CSO) management strategy to develop various plans to control CSOs in the future. The CSO control strategy plan development involved an extensive technology review. This included:

- Best Management Practices (BMP);
- Separation (either full or partial) of the combined system;
- Storage (with and without district transfers)
  - off-line
  - tunnel/transport
  - in-line
- High rate treatment
  - Retention Treatment Basins (RTB)
  - Vortex Solid Separators (VSS)
- Floatables capture.

An integrated modeling approach was used to determine how each of the various candidate options for CSO control would perform. The integrated modeling approach involved three types of models which were sequentially linked:

- an urban hydrology model to estimate the runoff from a wide-variety of rainstorms over the year;

- a sewer system/control alternative model to simulate behaviour of the hydraulic system and thus determine when and where overflows would occur, the volume of interception, the volume of overflow, and the benefits of various control measures; and

- a receiving stream model was used to assess the hydrodynamics and biokinetics of the river water quality, i.e., transport, mixing, fecal coliform die-off, etc., in response to dry and wet weather loadings from the full range of urban discharges.

The various alternatives were assessed in terms of their performance with respect to various performance measures such as number of overflows, volume of overflows and compliance with surface water quality objectives for the receiving streams.

SEWER SYSTEM CHARACTERISTICS

Winnipeg is a very flat prairie city located in the Red River Valley. Generally, the elevation difference throughout the City is about 3 to 4 m (10 to 13 ft.). The Red and Assiniboine rivers water level is only 3 to 4 m below street level along the riverbanks. In addition, the hydrology of the prairie region, which may be relatively dry compared to the East Coast cities, creates large and intensive thunderstorms at least once a year. These geographical factors resulted in the design of existing sewer systems for protection of basement flooding with very flat grades and large diameters.

During dry weather flow, all wastewater is diverted into an interceptor and subsequently conveyed by a gravity to one of three wastewater pollution control centers (WPCC) for full secondary treatment processing before it is discharged to the rivers. However, during wet weather conditions, flow into the system is significantly greater than dry weather flow (DWF) and results in combined sewage overtopping the diversion weir and spilling into the river.

A typical sewer in one of the 43 districts has a 3 m diameter pipe extending 2 to 3 km perpendicular to one of the rivers. During typical operation, the dry weather flow in the combined sewer occupies only a small depth in the bottom of the sewer. A low weir, 0.3 to 0.6 m in height, typically diverts dry weather flow (DWF) either directly into an interceptor or to a pump station where it is delivered to the interceptor. During severe rainstorms, these same sewers are often surcharged, however, significant sewer storage volume is available for more routine rainstorms and could be potentially accessed for use as in-line storage.

The original sewer designs in the city allowed for flood protection of up to a storm of a 1-in-2 year occurrence. Over the past three decades, the City has been upgrading the combined sewer system to allow protection from basement flooding for a storm of up to a 5-year occurrence. These sewer relief programs have often resulted in the addition of a second major sewer pipe in each combined sewer district of comparable size to the main combined sewer trunk (e.g., 3 metres). These relief pipes offers the potential for increasing the volume available for in-line storage in each district.

DEVELOPMENT OF IN-LINE STORAGE ESTIMATES

In-line storage is the latent volume contained within the existing sewer pipe network that can be safely accessed through the use of a control device. Specifically, the control device is intended to cause excessive flows in a the sewer system to be stored in the pipes up to a safe level that does not decrease the existing level of the basement of flood protection. Figure 1 illustrates a typical profile of a combined sewer trunk found in Winnipeg.

Preliminary analysis of Winnipeg's combined sewer system found that large volumes of in-line storage may be available and could significantly reduce the number and volume of CSOs in a cost-effective manner. Accordingly, it was necessary to conduct a detailed review of the combined sewer systems to assemble the data needed on pipe geometry and critical elevations (invert and ground) to improve the accuracy of in-line storage volume calculations for all 43 combined sewer districts in Winnipeg. Once this information was assembled, it was possible to calculate the volume of storage available in each pipe for a specified weir or control elevation.

During the course of the CSO study, the need to investigate the different in-line storage concepts and control technologies evolved. The following three control concepts are the most relevant to the Winnipeg situation.

- Automated gate control
- Fixed finger weirs
- Accessing existing passive / latent storage.

The following discussion elaborates on these three control concepts as they relate to Winnipeg's CSO study and relevant local circumstances.

Real Time Control Gate Option

A review of rainfall history (recent 35 years) was conducted to understand the number and size of rainfall/runoff events that Winnipeg typically experiences during the open water recreation season (May 1 to Sept. 30 inclusive). It was found that most rainfall events are well below the hydraulic capacity of the combined sewer and could be stored within the system. The use of an automated gate system to access available in-line storage by temporarily holding wet weather flows (WWF) within the system during and after small rainfall events is one option under consideration. Runoff from these small rainfall events could be completely stored within the combined sewer system and then dewatered during and after the storm event (see Figure 2b).

The gate control option was assessed to estimate receiving stream impacts. The gate, initially open and in the "home position", would shut during the start of a wet weather event and remain shut until the event was completely over and the sewer was dewatered unless the water level in the sewer rose to a specified critical condition. If the water level or the rate of rise met a predefined trigger condition at selected strategic locations within the sewer system, the gate could be operated in the following two different modes.

- continuous modulation of the automated gate to fully utilized in-system storage while maintaining the existing level of basement flood protection; or

- opening the gate fully and leaving it open to assure that levels in the sewer would not threaten basement flooding.

In the first method, the maintenance of the level in the sewer at an elevation that would not threaten basement flooding would maximize the volume of in-line storage. It requires accurate hydraulic representation of the sewer system under the range of gate operating procedures to achieve this available storage without a threat to basement flooding.

Other operating concerns related to repeated surcharging of the systems presented serious design considerations. There was concern that the modulating method may lead to waterhammer, air surges, weakening of structural integrity, and increased the formation of sinkholes in or along the sewer system due to repeated surcharging.

An alternative gate protocol was developed involving the release of all of the stored combined sewage whenever the water level reached the specified critical elevation. This operation would cause more volume of combined sewage to be released to the river. Since even a small overflow would likely cause a violation of the microbiological water quality objective (i.e., fecal coliforms) designated to protect recreation (either 200 fc/100 mL or 1,000 fc/100 mL), the number of overflow events throughout the recreation season would be the same regardless of the operating protocol used. It should be noted that the automatic gate operation can be accomplished by local, i.e., district-specific RTC, since each district acts as a relatively discrete watershed to the interceptor. The dewatering of the various in-line storage elements in the different districts may require a system-wide or global RTC.

A second consideration used in the development of the gate operation strategy was the selection of the specified target elevation below which the combined sewage could be safely stored without affecting the existing level of basement flood protection. The water level and/or its rate of rise would be closely monitored and used to initiate gate opening to maintain the existing level of service with respect to basement flood protection. A key factor in gate automation is the speed at which it could be opened to permit system hydraulics to react quickly enough to keep pace with changes in a storm intensity and associated runoff and inflows. The gate operation is considered to have a fully automated real-time control system. Selection of these "trigger" conditions would have to be developed using sophisticated computer modeling.

A Workshop involving North American and European experts was held on the operations of in-line storage systems to review and assess its practicability to local conditions. The session identified that, due to the very flat sewer grades found in Winnipeg, there was the potential that air could be trapped in pockets at the top of the sewer and result in a air surges during wet weather operation of the gates. These air pockets could cause air surges to develop in response to the rapid filling of the combined sewer system under close gate conditions and could translate into pressure surges in service connections of homes and businesses at various locations along the sewer system. To prevent this conditioned from forming, it was determined that in-system storage levels should not exceed the obvert elevation of the sewer pipe at the selected location for automated gate control. Due to the relatively flat grades of the sewers, limiting levels to this control elevation would still allow for substantial realization of available in-line storage in each combined sewer district.

A second constraint was placed on the water surface profile to maintaining existing basement flood protection levels. A minimum depth of 3.0 m (approximately 10 ft) below minimum ground level was used as the maximum elevation the water surface profile would be allowed to reach in order to protect against basement flooding under in-line storage conditions, i.e., depths greater than 3.0 m below minimum ground elevation were considered adequate to protect against basement flooding for the current level of service. Accordingly, the minimum elevation of either the obvert or minimum ground elevation less 3.0 m was used as the control elevation to estimate available in-line storage.

One of the primary concerns associated with the use of real-time control for an automated gate to access available in-line storage is the potential increase in basement flood threatening risk . In order to minimize basement-flooding risk associated with gate control to a "virtually fail-safe" condition, additional design factors were considered:

- inlet restriction on catchbasins should be utilized to reduce the rate of inflow into the combined sewer system and result in system flow hydraulics no worse than that generated by a one in five year synthetic design storm;
- the logic of gate control systems (with redundancy) have to be developed to open the gate if there is a malfunction or failure in any of the water level sensing monitors;
- gates would have to be designed to open automatically in case of power failures or interruptions (e.g., an air-accumulator connected to a hydraulic operator or an air-driven motor); and
- utilization of the existing flood pumping stations to initiate emergency dewatering of the combined sewer system if the gate fails to open, (e.g., shaft breakage or mechanical malfunction).

Fixed Weir Option

The control concept described above was considered to be "virtually fail-safe". Given a history of basement flooding, there was still concern about added risk of basement flooding to the citizens of Winnipeg under extreme contingencies. Accordingly, other alternatives, which were inherently fail-safe, were considered. A fixed weir utilizing long weir lengths to minimize flow depth over the weir was considered both fail-safe and practicable (see Figure 2c). This option requires the construction of a large weir chamber utilizing finger weirs in the sewer system to achieve the lengths of weir needed (60 m in some cases) to access available in-line storage. The weir chamber would be 13 metres wide, and fit within the roadway right-of-way. A design condition of 150 mm (6 inches) depth of flow over the weir to safely pass a 1-in-5 year design storm was selected. The existing hydraulic gradeline (HGL) for each sewer system under the design event was reviewed to establish the top elevation of the weir (i.e. each HGL-0.15 m).

To maintaining existing basement flood protection levels under this option, a minimum depth of 3.2 m (approximately 10.5 ft) below minimum ground level was used to protect against basement flooding. Accordingly, the minimum elevation of either (HGL less 0.15 m or minimum ground less 3.2 m) was used as the control elevation to calculate available in-line storage.

A fixed finger-weir system to utilize available in-line storage has the advantage of little need for operational attention relative to an automated gate control system and is inherently more fail-safe. However, it is more costly to construct and will only utilize about 80% of the in-line storage that could be achieved through the use of an automated gate control system.

Passive and Latent Storage

Many of the underground combined sewer districts have relief sewers to reduce basement flooding. The primary purpose of the relief systems in Winnipeg is to improve the hydraulic conveyance of wet weather flows (WWF)so as to protect basements from flooding for a given design level of service (e.g. 1-in-5 year return frequency storm). The relief systems are designed to be active (i.e., overflow to the rivers) only during rainfall conditions. As described earlier, a low-level weir was historically installed in the combined sewer trunk and used to redirect DWF through an off-take system to the interceptor system. The diversion structures were originally designed to divert about 2.75 times DWF. To avoid dry weather overflows from occurring in the relief systems, careful attention was placed on the hydraulic modeling and design of relief overflow activation levels. Specifically, hydraulics in both systems (combined sewers and relief piping) were synchronized such that overflow from the relief system did not occur prior to overflows from the combined sewer system. The storage of combined sewage contained in the combined sewer system up to this activation level represents existing passive in-line storage volume.

Currently, many of the relief sewer pipes that are part of the combined sewer systems are below normal river water level (see Figure 2d). Each relief system outfall has a flap-gate installed to prevent river water from entering the sewer system. The majority of these relief pipes do not have a dewatering system and remain partially full under normal river water level conditions. As such, the combined sewage will remain in the relief pipe between storms until it is displaced by flows resulting from the next rainfall event. If this combined sewage could be dewatered to the interceptor, a significant amount of storage would be available to store small storms, and accordingly is considered latent storage.

COMPARISON OF IN-LINE STORAGE AVAILABLE

In-line storage calculations were performed for each of the 43 combined sewer districts to quantify the potential volume of storage available for each of the 3 control concepts previously discussed (i.e., gate, weir, and latent storage). The results are summarized on Figure 3. The automated gate option allows for the greatest volume of storage to be utilized, about 360,000 m^3. The fixed-weir option achieves about 300,000 m^3 of storage. Accessing existing passive and latent storage would provide in the order of 130,000 m^3 of storage. The cost of the automated-gate option is about $ 50 Million compared to the higher cost for the fixed weir of $ 100 Million. The risk of failure associated with the automated-gate option must be considered and the economic penalty of failure accounted for in the decision-making process. In order to safely access in-line storage, (i.e., reassure the public that there is no increase in the risk to basement flooding), the fixed weir option may be the only option the public will support. Existing latent storage could be accessed now but would require dewatering facilities to be installed and ensuring flap gates are operating correctly. This cost associated with accessing latent storage would be significantly lower than either of the other two options.

INTEGRATION WITH FUTURE BASEMENT RELIEF PROJECTS

The City of Winnipeg has an ongoing program to improve basement flood protection on a prioritized basis. The most flood-prone combined sewer districts are ranked and given highest priority for installation of relief sewers. Figure 4 shows the combined sewer districts that have been relieved and the remaining districts that require some degree of relief to improve basement flood protection. An estimate of potential increase in the in-line storage that could result from new relief pipes, for each of the in-line storage control concepts considered is shown on Figure 3. The analysis indicates that latent storage could be significant if it were possible to install all new relief pipes at a depth that the normal river level would control (i.e., below river level and held back by flap-gates). Specifically, future relief projects could potentially achieve as much in-line storage as the existing system with an automated gate control scheme, although the distribution of the storage in the system may not be optimal. New relief projects represents a very important opportunity with respect to supplemental in-line storage volumes that could significantly reduce the need for more expensive and complicated control technologies. Clearly, the addition of new relief pipes can provide improved basement flood protection while reducing the number and volume of CSO. The need for CSO control provides the opportunity to expand the design criteria of proposed relief projects to include consideration of cost-effectively maximizing in-line storage and minimize wet weather impacts.

CONCLUSION

In-line storage can be a cost-effective method of reducing combined sewer overflows. The use of automated gate controls is one method of maximizing the use of the available in-line storage at a reasonable cost. Concerns from the public that this automated system may increase the risk of basement flooding under worst-case contingency events, even if the risk is very low, may preempt its use. Alternative methods such as use of fixed weirs and using latent storage may access significant in-line storage for CSO control

Designing future basement relief projects with due consideration for increasing latent storage may prove to be a very effective integrated long term CSO control solution.

Figure 1: Illustration of Potential In-line Storage in an Actual CS Trunk

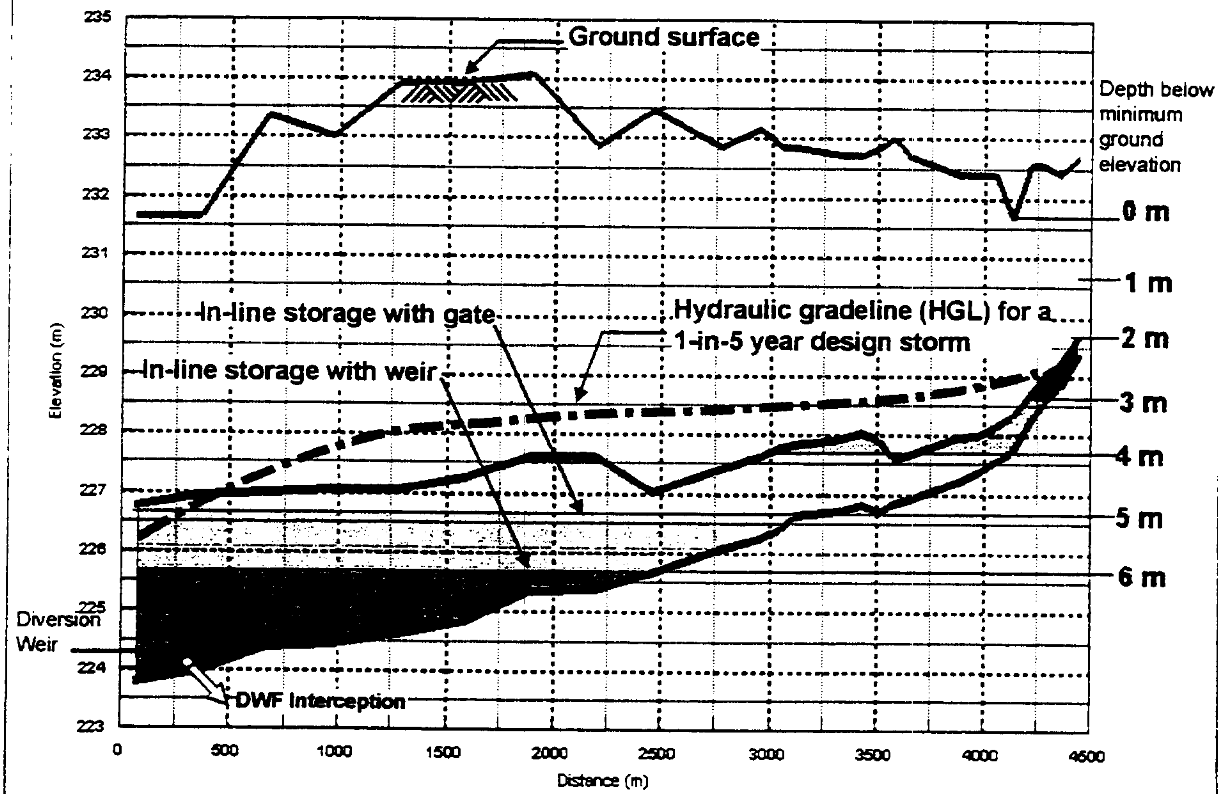
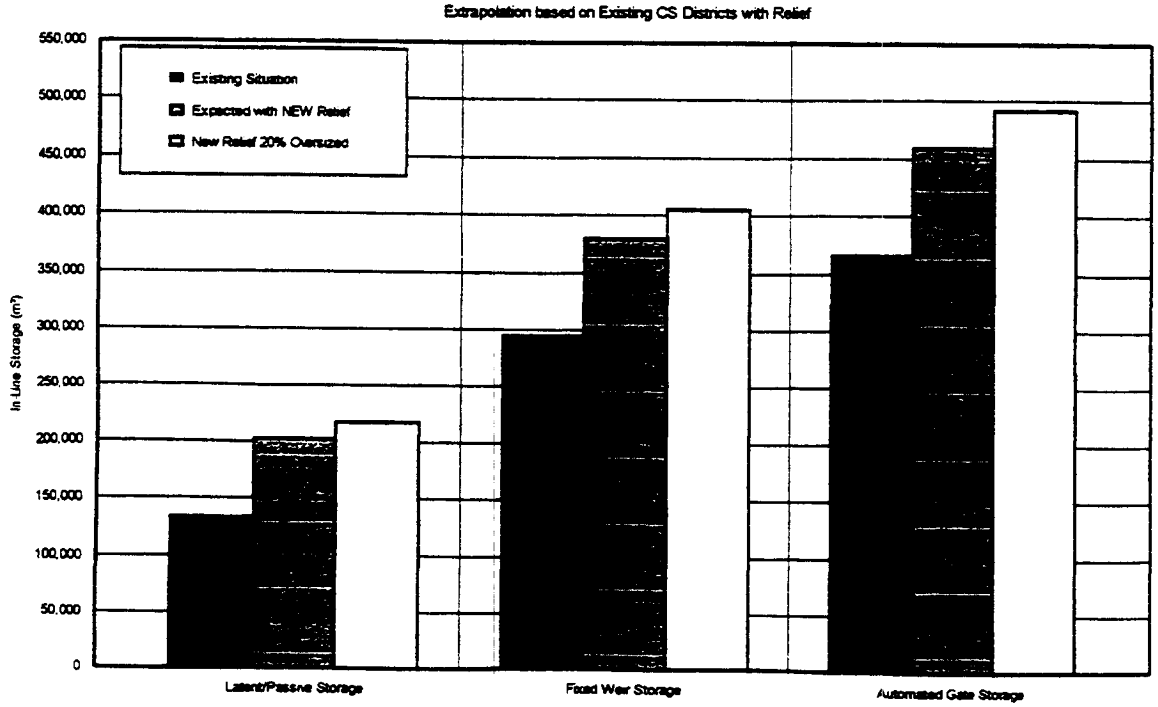


Figure 3: In-Line Storage Potential • Additional Volume Range

Extrapolation based on Existing CS Districts with Relief



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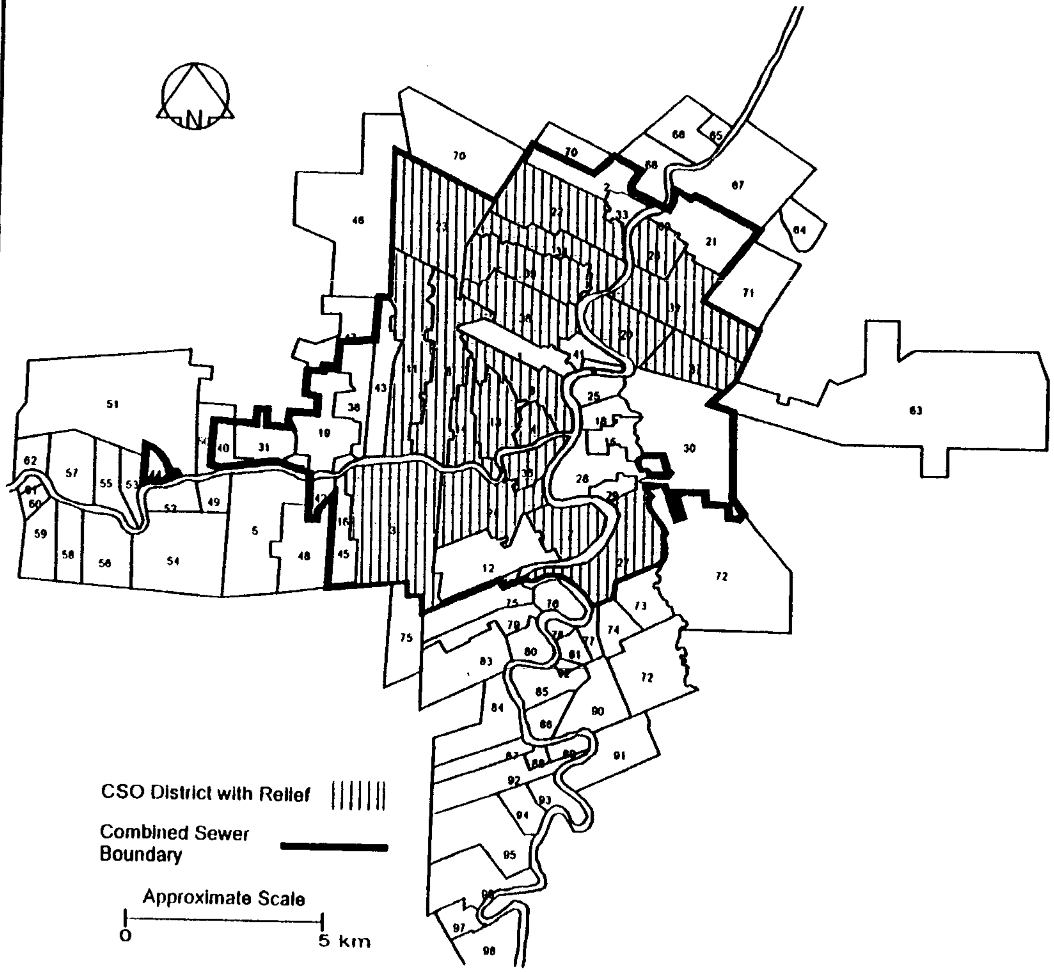

CSO Districts with Sewer Relief
Figure 4

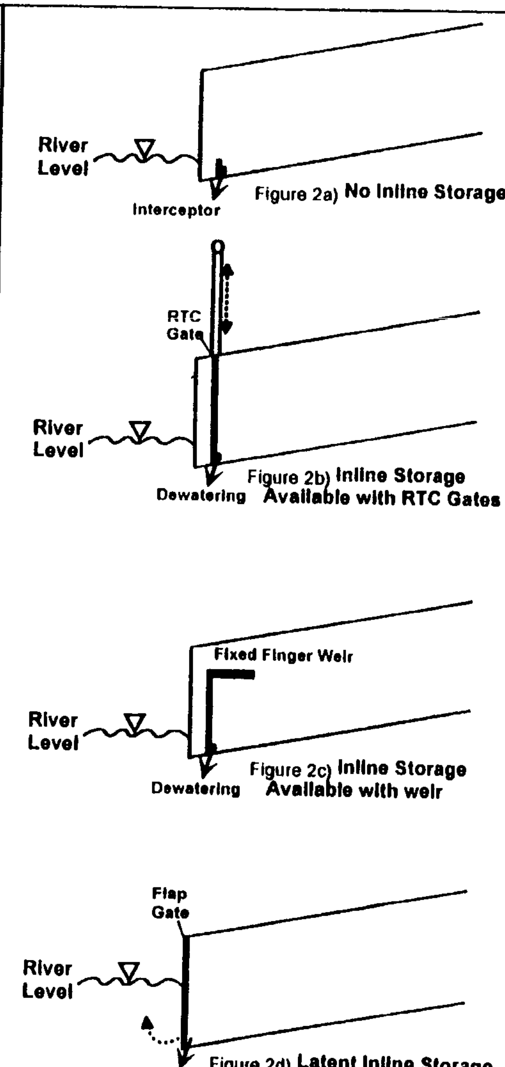

Figure 2a) **No Inline Storage**

Figure 2b) **Inline Storage Available with RTC Gates**

Figure 2c) **Inline Storage Available with weir**

Figure 2d) **Latent Inline Storage Available in relief pipe below river level. Dewatering facility must be installed.**

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CATCH BASINS - EFFECTIVE FLOATABLES CONTROL DEVICES

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ABSTRACT

One of the major issues of urban wet weather pollution is the control of floatable pollution. Studies conducted in New York City have shown street litter to be a major contributor of floatables to New York Harbor. Several methods for controlling floatables are being considered including increased street sweeping, end of pipe treatment technologies, booming and skimming at CSO outfalls and catch basin controls. Catch basins, which exist in most urban areas, offer a means of controlling floatable material at the source. They are simple devices which if properly maintained can be very effective in removing floatable material from stormwater. This paper presents New York City's efforts in evaluating the effectiveness of catch basins as well as a City-wide program to inspect, map and hood all catch basins.

Catch basin designs for most urban areas throughout the US are similar. The most important aspect of this design, with respect to floatables removal, is the presence of a hood or trap which is generally hung over the basin's outlet. The hood, which extends into the water surface, provides a seal which prevents the release of sewer odors into the surrounding neighborhood. The hood also acts as a baffle at the water surface which prevents the release of floatable material to the sewer system. Studies conducted in New York City have shown hoods to be capable of retaining 70 to 90% of floatables entering the catch basin.

New York City is implementing a City-wide catch basin hooding program as part of its CSO control program. This effort includes inspection, inventory and mapping of all catch basins. There are approximately 130,000 basins throughout the City. Following the inspections, basins are cleaned and hoods are installed where needed. The program, which is expected to be completed over a four year period, was started in February 1996.

A database is being constructed from the information being collected during the inspections, which includes approximately 150 data items per basin. GIS mapping of the basins is being integrated with the database to produce a comprehensive management tool which will be used to direct future catch basin maintenance and repair activities. This program, with periodic basin inspections, will provide a means of maintaining hoods on catch basins and thereby ensure the effective use of catch basins as a floatables control.

KEYWORDS

catch basins, floatables, combined sewer overflows

INTRODUCTION

The City of New York operates a wastewater collection and treatment system for approximately 1.4 billion gallons per day of sewage flow. The collection system covers approximately 190,000 acres of which approximately 120,000 acres are serviced by combined sewers. The City is in the process of developing a comprehensive plan for managing combined sewer overflows. The control of floatable pollution is a major component of this plan.

The City has conducted several studies since 1988 investigating sources and controls of floatable pollution. The primary source of floatables has been identified as street litter. Controls that have been or are currently being investigated include:

- booming and skimming
- catch basin hoods
- increasing wet weather flow capture at wastewater treatment plants
- enhanced street cleaning
- centrifugal separators
- in-line storage
- public outreach programs

Many of these controls have been adopted in the USEPA's Nine Minimum Controls for combined sewer overflows. The City has adopted booming and skimming as an interim control while a long term strategy is developed. Part of that long term strategy is the hooding of catch basins throughout the City.

The primary function of catch basins is to intercept and transport storm water from streets to a collection system. New York City has approximately 130,000 catch basins, most of which discharge to either combined or storm sewers. During wet weather events the catch basins receive storm water as well as litter scoured from the street by the storm water. The litter captured by the catch basins can be released to New York Harbor through storm water outfalls or combined sewer overflows. This pathway is believed to be a major source of floatable material found in the open waters and in beach wash-ups around the City.

Catch basin designs for most urban areas like New York City are similar (see Figure 1). They generally include a curb inlet or grate (or both), a sump and an outlet. Another common feature is a hood which restricts the venting of sewer gases through the catch basin (see Figure 2). It does this by covering the outlet pipe to a point 4 to 6 inches below the invert of the pipe. Typical catch basins hold water up to the outlet invert. The submergence of the hood creates a water seal which prevents the venting of sewer gases. The hood also acts as a baffle which prevents floating material, such as most street litter, from passing through the outlet. While many catch basin designs include hoods, these devices are often missing due to their own deterioration, deterioration of mounting hardware or accidental removal during basin cleaning or maintenance operations.

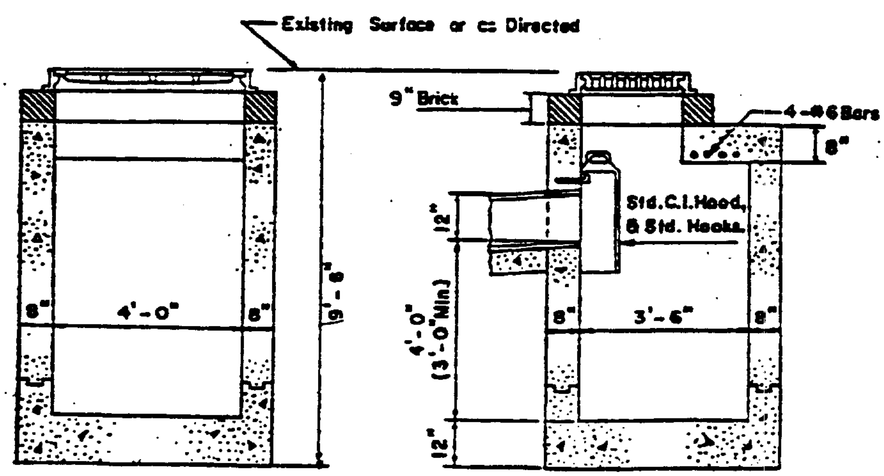

Figure 1 - Typical New York City Catch Basin

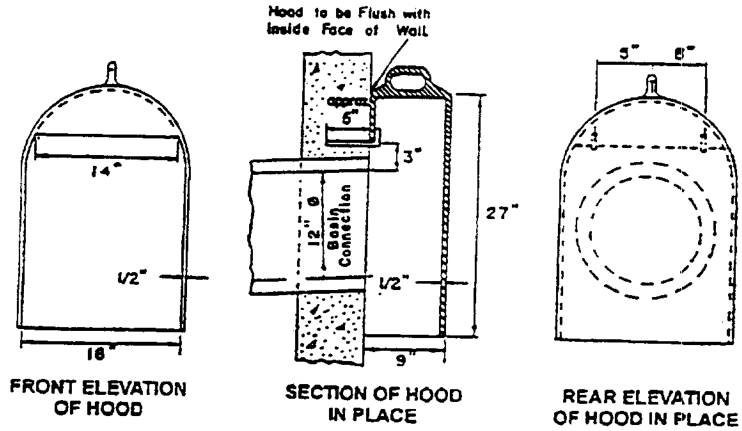

Figure 2 - Typical Catch Basin Hood

The effectiveness of hoods in their ability to retain floatables in the catch basin was investigated. This paper will present the methods and results of those studies as well as the catch basin hooding program which is currently being conducted in New York City.

METHODOLOGY

Two basic protocols were used to evaluate the effectiveness of catch basin hoods. The first protocol was developed for sampling the material discharged from catch basins to the sewer. The objective of the procedure was to develop estimates of the floatables loads discharged from catch basins as well as characterizing the material discharged. This test relied on rainfall events to transport street litter to the catch basins. The second procedure was a series of batch efficiency tests which used a synthesized litter matrix and a fire hydrant to simulate street runoff flows.

Both methods included the same sampling equipment and installation (see Figure 3). This included a 13"x13"x36" high galvanized mesh basket. The lower half of the basket was screened with ¼" mesh, the upper half with ½" mesh. The basket was positioned on a wooden platform in a manhole just beneath the catch basin outlet pipe. It was tethered to the wall of the manhole to permit placement and removal without having to enter the manhole.

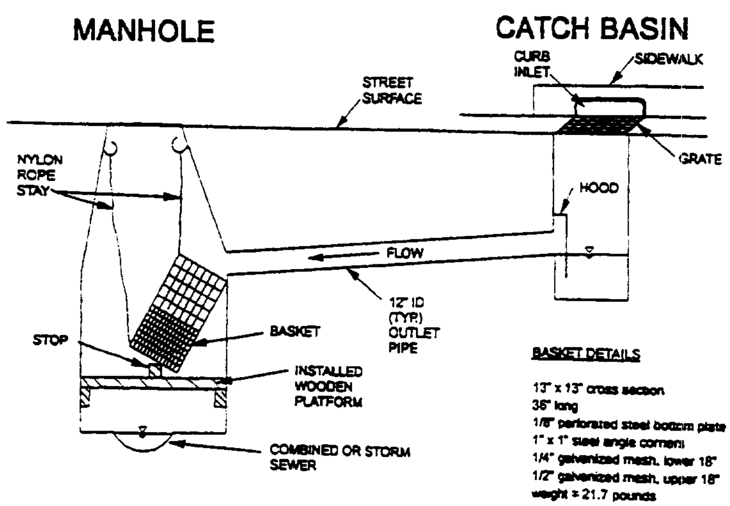

Figure 3 - Catch Basin Sampling Equipment

Catch Basin Sampling Protocol

In the first protocol sampling equipment was installed at 38 locations (six to ten in each of the five boroughs). The initial intent of this sampling program was to characterize material and loads released from catch basins. While selecting sampling sites it became apparent that approximately 60% of the City's catch basins did not have hoods. As a result half of the sampling sites selected had hoods, half did not. In addition to characterizing the loads and the material released from the basins, this also offered an opportunity to characterize the effectiveness of the hoods.

All 38 sites were continuously monitored for 3 to 4 months between the spring and fall of 1993. Eight sites were sampled weekly for approximately 4 months, the remaining 30 sites were sampled bi-weekly for approximately 3 months. The samples were collected by deploying the baskets for the one or two week sampling period after which the contents were transferred to a sample bag. The baskets were then replaced for the next sampling period and the samples were analyzed at a field laboratory. Sample analysis consisted of sorting the material into 13 material categories (see Table 1), measuring and recording the number of items, surface area and weight for each category.

Table 1 - Material Type Categories for Catch Basin Sample Analysis

	Category	Examples
1.	Sensitives	syringes, crack vials, baby diapers
2.	Paper-Coated/Waxed	milk cartons, drink cups, candy wrappers
3.	Paper-Cigarette	cigarette butts, cigarettes
4.	Paper-Other Products	newspaper, cardboard, napkins
5.	Plastic	spoons, straws, sandwich bags
6.	Polystryene	cups, packing material, some soda bottle labels
7.	Metal/Foil	soft drink cans, gum wrappers
8.	Rubber	pieces from autos, pieces from toys
9.	Glass	bottles, light bulbs
10.	Wood	popsicle sticks, coffee stirrers
11.	Cloth/Fabric	clothing, seat covers, flags
12.	Misc. Floatables	citrus peels, pieces of foam
13.	Non-Floatables	opened food cans, broken bottles, bolts

Efficiency Test Protocol

The second procedure involved seeding a street gutter or catch basin pit with ten pieces each of 12 different floatable items (120 items total). This matrix included the following common street litter items: plastic bags, candy wrappers, straws, bottle caps, juice bottles, hard plastic pieces, glass vials, aluminum cans, polystyrene cups and pieces, cigarette butts and medical syringes. Each unit of matrix also corresponded to a total volume of approximately 1 ft^3. A fire hydrant was used to provide a water flow of 75 gallons per minute which is equivalent to 0.28 inches per hour of rainfall over a 40,000 square foot drainage area. This rainfall intensity corresponds to the Maximum Likelihood Estimate (MLE) of the maximum hourly storm intensities at John F. Kennedy Airport for the 1988 to 1994 period of record. Additional tests were also conducted at 25 and 150 gallons per minute.

A sampling basket was placed beneath the catch basin outlet and flow was applied until no more floatable items passed to the basket (five to ten minutes). The items remaining in the basin and captured in the basket were separately retrieved and counted. This process was repeated 5 times for each test. Tests were conducted in this manner with and without hoods at seven sites. Ten tests were conducted in all.

RESULTS

The effectiveness of catch basin hoods in retaining floatables became apparent during the course of performing the catch basin sampling studies. Field observations also indicated that hooded basins exhibited an accumulation of floatables and litter while basins without hoods did not. The effectiveness of hoods was further supported by the results of the efficiency tests.

Catch Basin Sampling Studies

As stated previously, the objective of the catch basin sampling program was to estimate the floatables loads from catch basins to the sewer. The loads were developed on the basis of number of items, surface area and weight per linear foot of street or curb length tributary to the basin. The effectiveness of hoods became apparent when this data was reduced to hooded and unhooded basins (See Table 2).

Table 2 - Average Litter Loads and Impact of Hoods for Catch Basins Sampled During the Monitoring Program

Condition	Number of Items (No/100ft/d)	Surface Area (sq in/100ft/d)	Weight (gm/100ft/d)
Hooded	2.5	7.6	3.3
Unhooded	8.4	16	11
Load Reduction*	70%	53%	70%

*Load reduction is based on load without hood, ie = [(unhooded - hooded)/unhooded] x 100.

As shown in the table hoods reduced floatables by 53% to 70%. This should be viewed as a qualitative estimate of their effectiveness because the comparison is being made between two different groups of catch basins. Each basin in the study was unique with respect to the following variables all of which could also have affected performance:

- Tributary area which affects litter loads and runoff flow
- Street litter loads
- Basin type, dimensions and outlet alignment which affect turbulence within the basin under wet weather conditions
- Grit levels which may also affect turbulence

The efficiency test procedure eliminated these variables by permitting studies to be performed on the same basin with and without a hood.

Efficiency Tests

The efficiency test procedure was developed to be a direct way to evaluate the effectiveness of catch basin hoods. Eleven efficiency tests were performed and, in all cases, hooded basins exhibited a substantial reduction in the floatables load to the sewer (see Table 3). This reduction averaged 72% for the number of items discharged and 85% for the surface area of the items discharged. This is believed to be a more quantitative assessment of their effectiveness because the other variables which may affect performance were held constant.

Table 3 - Summary of the Floatables Capture Efficiency of Catch Basin Hoods Using the Efficiency Test Procedure

Test No.	Flow	Percent of Floatable Items: Discharge to Sewer: Hood	Percent of Floatable Items: Discharge to Sewer: No Hood	Percent of Floatable Items: % Improvement*	Percent of Surface Area: Discharge to Sewer: Hood	Percent of Surface Area: Discharge to Sewer: No Hood	Percent of Surface Area: % Improvement*
1/2	78	7.1	40.1	82	9.1	38.3	76
3/4	156	16.1	45.2	64	9.4	48.4	81
5.6	78	2.8	6.8	59	0.6	11.0	94
11/12	75	7.7	21.8	65	0.7	10.2	93
22/25	25	0.2	12.6	98	0.0	7.2	100
23/24	150	8.0	23.8	66	2.3	6.2	63
13/14	75	22.5	39.0	42	11.9	24.6	57
15/16	78	21.9	62.2	65	6.7	66.5	90
17/18	78	6.9	45.3	85	0.2	41.0	99
37/38	78	3.0	35.3	92	0.5	28.0	98
Overall Average Improvement				72%			85%

*Improvement with respect to performance without hood = [(no hood - hood) / no hood] x 100.

An obvious effect of the use of hoods in catch basins will be the accumulation of floatables and other litter in the basins. This raises a question. Will the efficiency of hoods decrease as floatables and litter accumulate in the basin? If so the use of hoods could require more frequent cleaning to keep their effectiveness at a maximum. This was investigated using a modification of the efficiency test protocol. The basic difference was that larger units of matrix were used (two cubic-feet) and the material retained in the basin was not removed, rather, it was allowed to accumulate. Only the items discharged from the basin were collected and analyzed.

Floatables capture efficiency for the particular basin studied was initially 93% (see Figure 4). This gradually declined to 86% as the basin became approximately 56% full of accumulated matrix. This test demonstrated that the accumulation of floatables and litter in a hooded catch basin does not adversely impact a hood's

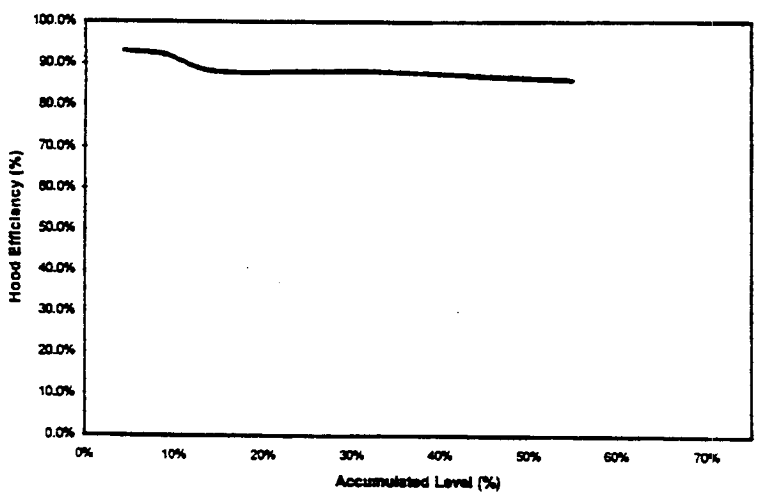

Figure 4 - Effect of Litter Accumulation on Hood Efficiency

performance. It may impact the hydraulic performance of the basin and cause premature flooding. This aspect of catch basin hoods as well as additional floatables and litter accumulation tests are scheduled to be performed in the future.

DISCUSSION

The studies presented in this paper demonstrate that catch basin hoods can reduce the release of floatables to any collection system (combined or separate) by approximately 70 to 90%. Based on these results a City-wide catch basin hooding program was started in February 1996. This program encompasses the entire 190,000 acres serviced by the City's collection system, including combined and separately sewered areas. This program is being conducted in three phases:

Phase I	44,000 structures	Areas with high street litter loads and existing controls in less than 50% of the drainage area.
Phase II	58,000 structures	Areas with moderate street litter loads or no existing controls.
Phase III	28,000 structures	All remaining areas of the City.

In implementing catch basins as a floatables control technology, the City is going beyond ensuring that hoods are simply placed on the catch basins. All catch basins are being fully inspected and located on an accurate computer based curb-line base map of the City developed from recent aerial photography. ArcView (ESRI) is being used to develop the GIS application which will employ the base map. The inspection data is being incorporated into a database which is also linked to the catch basin map. This provides a comprehensive GIS management tool which will be used to manage and maintain the City's catch basins.

The basins are being inspected by field crews who record information on approximately 150 different data items such as the basin's location, type, dimensions, and condition. Each basin is permanently stamped with a unique six digit tag number which is entered into the database and the ArcView map.

Reports indicating basin cleaning and hooding needs are prepared for each of the City's fifty-nine Community Districts. These reports are used to direct the work of catch basin maintenance contractors who clean the basins and replace the hoods. The contractors maintenance activities, as well as the City's, are documented and also incorporated into the database to develop a maintenance history for each catch basin.

The approximate costs for this program are as follows:

Inspection, database and mapping	$45 per basin
Catch basin cleaning	$170 per basin
Catch basin hooding	$45 per basin
Contractor oversight	$23 per basin

To date, all Phase I inspections, cleaning and hooding have been completed. Phase II inspections will be completed by June 1998 and cleaning and hooding of these areas is expected to be completed by November 1998. Phase III work is expected to be completed in 1999. The City has also instituted a catch basin reinspection program which will be performed every two years. This inspection will determine if a basin requires a hood or if it needs to be cleaned. This is being done to ensure that hoods are maintained on the basins.

Between 1993 and 1995 the City instituted an interim floatables containment program (IFCP) consisting of the installation of 23 containment booms and four skimmer vessels. The installation of these facilities was based on pilot studies which demonstrated that containment booms reduced open water floatables by approximately

71%. The IFCP currently encompasses approximately 52% (62,000 acres) of the total CSO drainage area of the City.

As the hooding program proceeds through Phase II, the hooding coverage will encompass most of the IFCP drainage areas. As catch basin hooding is completed in each drainage area an attempt will be made to access the hooding programs effectiveness by reviewing IFCP loads before and after hoods were installed. Other information to be considered in the analysis will be rainfall records and street litter loads for both periods.

ACKNOWLEDGMENTS

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EVIDENCE OF A CRITICAL VELOCITY IN UNDERFLOW BAFFLE DESIGN FOR FLOATABLES CONTROL IN COMBINED SEWER OVERFLOWS (CSOs)

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ABSTRACT

Underflow baffles have gained in popularity over the last few years as a viable mean to intercept floatables in Combined Sewer Overflows (CSOs). This has happened in consideration of the extremely low application cost of the solution although the efficiency of underflow baffles has never been clearly proven. Furthermore, there are no guidelines helping planners in the correct and efficient design of underflow baffles. For this reason, review of the behavior of floatables in a rapid flow is paramount. Subsequently, comprehensive design criteria for the underflow baffle itself and the overflow chamber can be deduced. Pilot scale tests, performed in a 17 meters long basin at various flowrates, show that a critical horizontal velocity for floatables may develop in the overflow chamber (V_{cr}). Whenever this critical velocity is exceeded, floatables that would normally rise to the surface are kept within the flow and can consequently not be intercepted by surface restrictions. In other words, the underflow baffle cannot, under specific flowrate conditions, be effective in intercepting floatables. The equation relating the critical horizontal velocity to the vertical velocity in still water of any given floatable type is found to be : $V_{cr} = 16\, w\, R_H^{\ 1/6}$, where w is the vertical velocity in still water and R_H is the hydraulic radius of the pipe. This deduced criteria can also be used to evaluate the efficiency of existing overflow chambers. Preliminary analysis of existing chambers show that interception efficiency of floatables using underflow baffles can be, at best, very low.

INTRODUCTION

The presence of floatables in Combined Sewer Overflows (or CSOs) represents a pollution that is both aesthetically unpleasant, affecting harbors, beaches, coves and river beds, and a source of physical and chemical pollution. Floatables have also been known to impede propellors and cause navigational hazards in harbors (St-John *et al.*, 1994). The USEPA recenses approximately 11000 CSOs in 1100 American cities and towns (EPA, 1994). Removal of floatables from these remaining CSOs is one of the Nine Minimum Controls required under the April, 1994 EPA CSO Control Policy (EPA, 1994a).

Utilisation of underflow baffles in front of overflow weirs for control of floatables in CSOs is one of the several technologies considered by EPA. The Agency recommended it as a short-term BMP and, also, as part of long-term solutions. This technology has attracted much interest from consultants and utilities, due to its apparent simplicity, low cost and, especially, advantages in the operation and maintenance (O&M). All this took place although the actual efficiency of the underflow baffles has never been clearly demonstrated.

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In this context, we have been actively pursuing the study of interception of floatables in CSOs using baffles. ***The objective of this article is to present the results of experimental data leading us to believe that a critical velocity exist rendering the underflow baffle ineffective unless some very severe design conditions are respected.***

DEFINITIONS

Floatables are solids that are lighter than water ($\rho_{SOLID} < 1000\ kg/m^3$). In favourable circumstances, they tend to rise to the surface of the flow. These floatables are divided in two categories according to their state in the flow:

1. If they are suspended within the flow, by the action of turbulence, they are called swimming solids. ($\rho_{SOLID} \cong 1000\ kg/m^3$)
2. If they are floating on the flow surface, they are called floating solids.

It should be noted that some suspended solids that initially behave as floatables, would turn to settleable solids after becoming saturated with water. Furthermore, a given floatable at a given time may be either swimming or floating, depending upon hydraulic conditions of the flow, i.e. according to the velocity of the flow. The comprehension of this concept is crucial for the deisgn of efficient underflow baffles.

The critical velocity concept

The transport of floatable solids in a suspended state (swimming) is due to the condition of the flow. It is generally accepted that the turbulence lifts upward the settled solids from the bottom and drags downward floating solids from the surface. In laminar flow, all "heavy" solids would gather at the bottom of the channel and all light solids would float at the surface of the flow, as it is the case in a gentle stream or a stagnant body of water.

Previous work done on oil-water separators by the petroleum industry have shown that a critical velocity (V_{cr}) of oil globules exists in the flow. Conclusions from these research project have shown that an horizontal velocity of 15 times the vertical velocity of the oil globules will refrain the oil globules from reaching the surface, keeping them in suspension in the flow (API, 1990).

$$V_{cr} \cong 15w \qquad \text{(Eqn 1)}$$

where :

V_{cr} = Critical velocity of the oil globule in the separator, in (m/s);
w = Vertical velocity of the design oil globule in still water, in (m/s);

Floatables found in an overflow chamber during a CSO event can be assimilated to oil globules in an oil-water separator. Does the same phenomenon apply to floatables in overflow chambers as encountered in CSOs? It is evident that the wide composition of floatables in CSO's will generate a wide range of vertical velocities. A good knowledge of the floatables vertical velocity distribution is then paramount. If this were the case, the evidence of a critical velocity (V_{cr}) would mean a large difference in the optimal design of a baffle.

If the average horizontal velocity of the flow in an overflow basin is lower than the critical horizontal velocity, the swimming floatable should rise towards the surface without dropping back by the action of the turbulence. On the other hand, if the average horizontal velocity of the flow is greater than the critical horizontal velocity the suspended floatables should remain imprisoned in the flow and could not be intercepted by the baffle.

METHODOLOGY

Floatables used for the essays.

The floatables used in these tests correspond to those sampled in the Greater Montreal area as described in Paradis *et al.* (1996). A total of 51 experimental classifications representing all 2021 intercepted items were formed. The principal representative of CSOs are: cigarette butts (1045), Q-Tips (169), plastic debris (118), candy wrappings (101), polystyrene debris (72), preservatives (47), etc...

Description of the essays.

Hydraulic essays were conducted in a channel 1 m wide and 17 m long at the Hydraulics Laboratory of the École Polytechnique of Montreal. These studies had the objective of verifying the existence of a critical flow velocity (V_{cr}) for floatables, for a given efficiency and a given chamber length, and to relate it with the vertical velocities of the floatables as in the API studies. The critical velocity will therefore be expressed as $V_{CR\ \%,D}$, the critical velocity not to exceed to reach a given percentage (%) of removal of floatables for a given length of chamber D.

Figure 1 shows the trajectory of a floatable and the different dimensions used in the definition of terms K_1 and K_2.

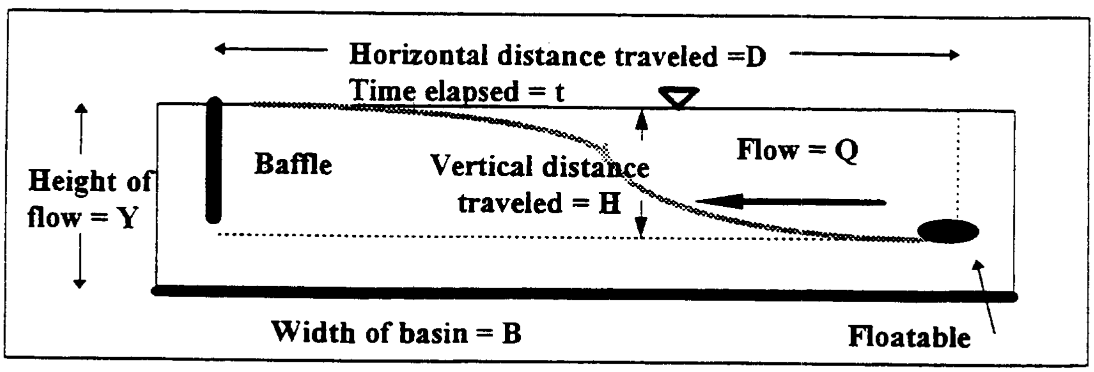

Figure 1. Schematic view of a channel used for the vertical velocity essays

The K_1 Ratio.

The parameter K_1 measures the ratio of horizontal velocities of the floatable in the flow. K_1 is defined as :

$$K_1 = \frac{V'}{V} \text{ (Eqn 2)}$$

where

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$$V = \text{Average horizontal velocity of flow in basin} = \frac{Q}{YB} \text{ ,in (m / s)}$$
$$V' = \text{Horizontal velocity of floatable in flow} = \frac{D}{t}\text{, in (m / s)}$$

The K_2 Ratio

On the other hand, the rise of floatables is studied through the relation K_2 defined as:

$$K_2 = \frac{w'}{w} \text{ (Eqn 3)}$$

w' = Vertical velocity of a floatable in a flow $= \frac{H}{t}$, in (m / s)

w = Vertical velocity of a floatable in still water, in (m / s)

The Rouse number

The influence of turbulence is given in relation to the Rouse number (Z) as described by Simons *et al.* (1977) and Van Rijn (1984). This number is mainly used in transport of sediments.

$$Z = \frac{w}{\kappa U*} \text{ (Eqn 4)}$$

where

κ = Van Karman constant = 0.4

w = Vertical velocity of a floatable in still water (m / s)

$$U* = \text{Root–Mean Square turbulent velocity component} = Vn\sqrt{\frac{g}{R_h^{1/3}}} \quad \text{(Eqn 5)}$$

and

n = Manning coefficient = 0.017 for our concrete basin

g = Gravity accelaration = 9.8 m / s^2

R_h = Hydraulic radius of the cross section of the basin, in (m)

Experimental protocol

An essay consists of the release of the floatable, in the flow, at a given proportion of the depth of the channel, ranging from 20% to 50% of the total water depth. Two informations are retrieved for each essay: the horizontal distance travelled (D) and the elapsed time (t) for the floatable to reach the surface. Whenever a floatable does not reach the surface, its elapsed time to reach the surface is infinite and therefore its vertical velocity is considered nil. Ten repetitions of the release for each of the floatable were done to obtain a significative average and median. The horizontal water velocity in these experiments ranged from 0.2 to 1.4 m/s. Twelve categories of CSOs were used in 8 sampling campaigns for this study for a total of 75 experimental points. Vertical rising velocities for a particular floatable are ranked in descending order for a serie of 10 essays. The vertical velocity of the 8^{th} element of the ten essays represents the minimal velocity ($w'_{8/10}$) to obtain an efficiency of 80%. In a number of tests, some solids released in the flow at different depths were not able to rise to the surface for the entire length of the test channel. These pilot-scale essays seem to confirm the existence of a critical velocity ($V_{cr, \%, D}$) for floatables in CSOs.

R0025042

RESULTS

The K_1 ratio

Results show that the horizontal velocity of the floatables is roughly stable throughout the flow. We also noted that K_1 is not greatly affected by the turbulent flow and corresponds to the average horizontal velocity of the flow. The numerical value of K_1, for all practical purposes, is therefore of 1. This means that we can correctly hypothesise that the horizontal velocity of the floatable is the same as the velocity of the flow.

The K_2 ratio

A graph of K_2 in function of U* is presented in Figure 2. In this case, results show that vertical velocities can be enhanced or hindered according to the value of the root-mean square velocity of the turbulent flow (U*). A turbulent velocity ranging between 0.015 et 0.035 m/s will, on average, ameliorate vertical velocities by a factor of up to 20% when compared to the vertical velocity measured in still water. Higher turbulent velocities will, on average, create adverse situations where the vertical velocity will be greatly reduced. A very high intra-essay variability was measured for each of the replicates, ranging from 25 to 50% of the mean values. These large variations are to be expected when dealing with such random events. The error bars plotted on the experimental data show that for the turbulent velocity range previously discussed, 0.015 to 0.035 m/s, the vertical velocity of the floatable can range between an increase of 50% or a decrease of 30% from the average vertical velocities values. Outside this range, the vertical velocity diminishes as soon as the turbulent velocity increases, reaching as low as 20% of the vertical velocity in still water.

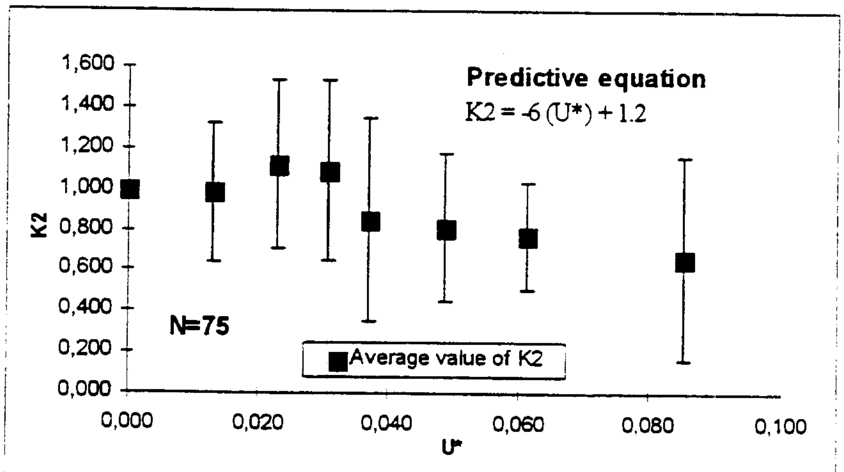

Figure 2. Graph of K_2 in function of U*

The critical velocity, V_{CR}, %, D

Finally, Figure 3 shows a graph of the Rouse number (Z) calculated for each of the essays in function of the minimal vertical velocity necessary to obtain an 80 % efficiency ($w'_{8/10}$) for a chamber length D. This curve shows that an exponential relationship exists between the Rouse number and the vertical velocity necessary to obtain an 80% efficiency in floatable removal. Although there is a lot of dispersion in the experimental points and a low coefficient of correlation derived from the data, the general trend of the curve is well established. Fifty of the 75 experimental data points falls between the minimal and maximal lines of influence. The critical horizontal velocity in the flow is obtained when the vertical velocity of the 8th element tested is equal to zero, i.e. when $w'_{8/10}$ is equal to zero. This means that the 8th floatable never reached the surface and was not intercepted by the underflow baffle. The critical Rouse number found in our data is $Z_{CR,\ 80\%}$= 2.89 when $w'_{8/10}$= 0 m/s. The basic tenet of this analysis is that a floatable that doesn't reach the surface in 17 m will probably never reach the surface. In this sense, the notation $Z_{CR,\ 80\%,\ D}$ becomes $Z_{CR,\ 80\%,\ D=\infty}$.

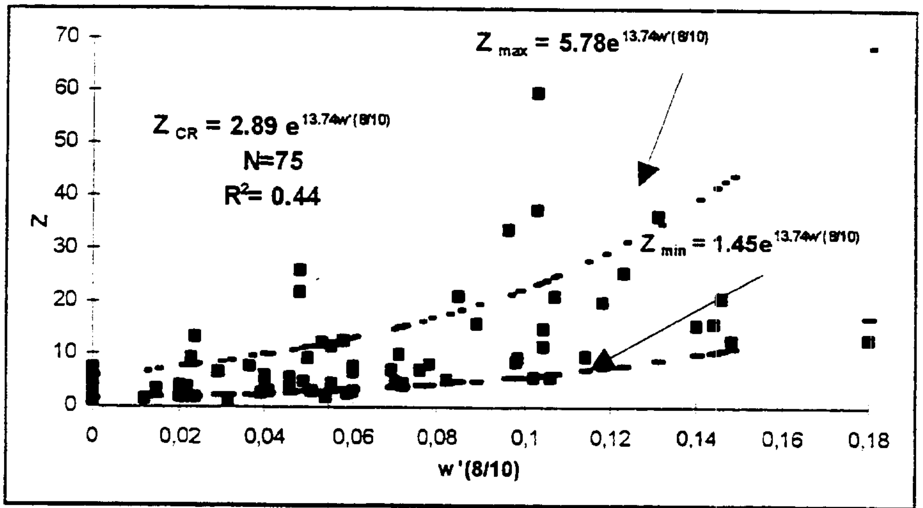

Figure 3. Graph of Rouse number (Z) in function of w'(8/10)

Determination of the critical velocity

It is possible to relate the critical Rouse number exhibited in a flow to the horizontal critical velocity ($V_{CR\ \%,\ D}$). By simultaneously solving for U* in equations 2 and 3, it becomes possible to isolate $V_{CR\ \%,D}$.

$$U^* = \frac{w}{\kappa Z} \quad \text{(Eqn 6 derived from Eqn 2)}$$

$$U^* = \mathrm{Vn}\sqrt{\frac{g}{R_h^{1/3}}} \quad \text{(Eqn 3)}$$

Combining equations 6 and 3, it becomes possible to solve for the horizontal velocity, V.

$$\frac{w}{\kappa\ Z} = \frac{nV\sqrt{g}}{R_h^{1/6}}$$

$$V = \frac{wR_h^{1/6}}{\kappa\ Z n\sqrt{g}} = wR_h^{1/6} \cdot \left(\frac{1}{n\kappa\ Z\sqrt{g}}\right) \quad \text{(Eqn 7)}$$

If we introduce the critical Rouse number (Z_{CR}) found earlier and the numerical values in the right hand terms, we can derive an expression for the critical horizontal velocity of the flow.

$$V_{CR} = \frac{wR_h^{1/6}}{\kappa\ Z_{CR}\ n\sqrt{g}} = 16\,w\,R_h^{1/6} \quad \text{(Eqn 8)}$$

The results of our hydraulic study indicate that a experimental coefficient of 16 in Equation 8 is valid for a removal efficiency of 80% of the floatables in our experiments and a chamber length of 17m.

CONCLUSIONS

A critical horizontal velocity (V_{CR}, %, D) can develop in overflow chambers under certain hydraulic conditions. Floatables found in the flow when this critical velocity occurs will refrain it from reaching the surface. Therefore, this critical velocity greatly influences the configuration and design of the overflow chamber. Presently, this critical velocity is not taken into account in the design of underflow baffles. Although an inexpensive solution, this renders inefficient existing overflow chambers outfitted with underflow baffles. Two different approaches can be explored to correctly control floatables : stricter design rules should be provided in order to insure a better interception efficiency of floatables or investment in more sturdy and reliable equipment installed in the overflow chamber, like bar screens, for example.

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WESTERLY DISTRICT INTERCEPTORS - INSPECTION AND EVALUATION PROJECT BENEFITS AND LESSONS LEARNED

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ABSTRACT

The Northeast Ohio Regional Sewer District (known hereafter as the District) owns, operates and maintains a large network of interceptor sewers and combined sewer overflow (CSO) sewers in the Cleveland metropolitan area. The District undertook the Westerly District Interceptors - Inspection and Evaluation Project to assess the condition of the interceptors and CSOs, the first in a series of large infrastructure assessment projects planned.

Several inspection and evaluation techniques were utilized. Many benefits and lessons were learned and rehabilitation recommendations were developed as a result of the project. During the period of October 1996 to September 1997, extensive inspection and evaluation was performed on over 200,000 lineal feet of sewers and appurtenances (manholes, regulators, hydrobrakes, etc.). Depending on the pipeline and flow characteristics, several inspection technologies including closed-circuit television (CCTV), manual walk-through, sonar and subsurface geophysical (Seismic Tomographic Imaging (STI)) were used. with varying degrees of success.

The Westerly project established several guidelines for future District condition assessment projects. Guidelines were established for manhole and pipeline defect classification and procedures for condition assessment were also developed.

INTRODUCTION

Project Description

The District owns, operates and maintains the large-diameter interceptor sewers and combined sewer outfall sewers serving the greater Cleveland metropolitan area. Some of these large conveyance sewers are more than 100 years old. The Westerly District Interceptors Inspection and Evaluation Project was undertaken to locate and assess the current condition of interceptors, combined sewer overflow (CSO) pipelines, and dry weather outlet (DWO) pipelines throughout the Westerly project area (shown in Figure 1). The project was a first step towards developing a comprehensive facilities plan for the Westerly District, which includes a detailed CSO facilities plan.

Inspection information was to be used to recommend and prioritize sewer rehabilitation projects that serve as a basis for a capital improvement program for the coming years. The scope of the project included:

- Documenting the structural and operational condition of the manholes and pipelines;
- Identifying and verifying interceptor and CSO flow routes;
- Locating and mapping all interceptor and CSO conduit manholes; and
- Identifying rehabilitation needs and estimated rehabilitation costs.

Work on the project consisted of five tasks:

- Assembly and review of background information;
- Inspection of manholes, interceptors and CSOs;
- Perform condition assessment based on inspection tapes, photographs, and field records;

- Development and implementation of a data management system; and
- Project administration - including project workshops and meetings.

Several different inspection techniques were utilized based on the pipe and flow characteristics. For pipes small than 66 inches, closed-circuit television inspection was performed. If flow levels permitted, walk-through inspections were performed on pipes greater than 66-inches high. Sonar inspection was performed on pipes with large amounts of known debris, or flow depths greater than half-full (50% of depth) and fully submerged pipes. Subsurface geophysical investigations (Seismic Tomographic Imaging (STI)) was utilized on the Westerly Interceptor near the site of a previous sewer collapse, and on a branch of the Walworth Interceptor under Interstate 90.

Description of Project Area

The Westerly Wastewater Treatment Center (WWTC) is located at 5800 West Memorial Shoreway in the City of Cleveland. It currently serves approximately 110,000 residents, primarily from the west side of Cleveland. An estimated sewered area of approximately 10,000 acres (15.6 Sq. Miles) is currently tributary to the WWTC and its general boundaries are the Cuyahoga River to the east, the Rocky River to the west, Lake Erie to the north and Big Creek generally forms the southern boundary of the tributary area. There are four main interceptor systems in the Westerly District – Low Level interceptor, Northwest Interceptor, Westerly Interceptor, and the Walworth Run Interceptor. Additionally, there are 26 CSO pipelines that carry wet weather flows to the local receiving streams and Lake Erie. Construction of the interceptors in the Westerly District was begun in the early part of the century with the construction of the main branch of the Walworth Interceptor and the Westerly Interceptor. The Low Level interceptor was constructed in the 1930's and the Northwest Interceptor added in the late 1970's.

Known problems in the interceptor system include:

- Considerable grit and sediment in the Low Level interceptor.
- Inspection concerns at the seven hydrobrakes (storage structures) in the Northwest Interceptor, and debris that is known to accumulate immediately upstream of the hydrobrakes.
- Collapse of the Westerly Interceptor from Desmond Avenue to West 65th Street in the vicinity of the Consolidated Railroad (Conrail) tracks in 1994. Soil subsidence is still noted along the repaired route of the Conrail collapse, between Lake Avenue/Desmond Avenue to West 65th Street
- Flows in the Westerly Interceptor are controlled to minimize CSOs, even if this normally results in surcharging the brick line.
- There were no known major structural and operational problems in the Walworth Interceptor.

Sewer Characteristics - Sizes and Lengths

The size of the sewers contained within the Westerly Interceptors ranges from 6-inches (dry weather outlets from combined sewer overflow regulators), to 108-inch by 240-inch box culverts at the downstream end of the Northwest Interceptor, at the entrance of the Westerly Wastewater Treatment Center. This very large range presented challenges to the inspection crews. Several different inspection contractors and inspection techniques were employed to ensure that complete information was gathered from all types of sewers. The distribution of sewer sizes in the Westerly District Interceptors is summarized in Table 1. A breakdown of sewer lengths in summarized in Table 2.

METHODOLOGY

Defect Identification Guidelines

Prior to commencement of the field inspections, the project team established inspection criteria and defect identification codes to ensure that the inspections would be conducted in a consistent manner and produce reliable data. Specific criteria were developed to identify structural and operational condition defects that might be found in manholes and sewer pipes. An important product of this project was the Manual of Sewer Defect Classification. This manual is now being utilized in a current District project and will be utilized in all future inspection and evaluation projects. It help ensure that subsequent District inspections are performed in a similar manner to the inspections performed on this project and that inspection defects are encoded correctly and consistently.

Table 1 Summary of Sewer Information

# of Pipe Segments	Total Length of Pipe (ft)	Pipe Size Range	Sewer Shape	Sewer Length (ft)	Sewer Material	Sewer Length (ft)
867	226575	Minimum	Circular	185873	Brick	111083
(MH to MH)		6" (DWO's)	Egg	28742	Cast-in-Place	2637
			Rectangular	7485	CMP	2473
		Maximum	Elliptical	2642	DIP	116
		108"x240"	Unknown	1833	PVC	57
		(Northwest)			RCP	99735
		(Northwest)			VCP	10154
					Unknown	320
Totals	*226575*			*226575*		*226575*

Table 2 Summary of Length of Sewer by Pipe Sizes

Pipe Size	Total Length	Low Level	Northwest	Walworth	Westerly	CSOs-DWOs
<15	3074	486	0	18	0	2570
15-24	13907	5055	0	1441	1567	5844
27-36	18845	5167	1990	879	2309	8500
39-48	19036	0	0	3905	1882	13249
49-60	32767	5775	324	6439	7095	13134
61-72	33440	0	1307	11262	7394	13477
75-96	37536	0	4504	3266	6881	24241
98-120	45072	0	33336	5665	2692	2023
121-240	16543	8	4284	6019	0	6232
#7-#15 Egg	5794	1440	0	827	325	
Other	561	0	0	0	0	3202
Totals	*226575*					

Internal Condition Assessment

A key part of a rehabilitation program is to translate the defect data into repair and rehabilitation needs. This process considers the severity of a defect or defects and assigns the sewer reach an "*internal condition grade.*" Internal condition grades were developed by assigning a score for a specific defect and summing those defect scores. The Westerly project utilized a condition assessment grading system with 5 grade levels. The five internal condition grades for the project are defined as shown in the Table 3.

Rehabilitation

Upon assignment of the structural and operational condition grade of the sewer, a rehabilitation level was developed for each segment of sewer. During the Westerly project, several possible levels of rehabilitation assignments were utilized. The levels of rehabilitation are:

- **Level 1** Continue monitoring periodically (required for all sewers - typically recommended every 5-10 years).

- **Level 2** Perform maintenance of the existing system. Examples include cleaning, local repairs, replacement of manhole covers, etc.
- **Level 3** Stabilize the existing system. Examples include repointing of the brickwork to prevent further deterioration or external grouting.
- **Level 4** Structural relining of the existing sewer. This option may be accompanied by the construction of other relief facilities if capacity problems are an issue.
- **Level 5** Replace or abandon the sewer. The structure is completely deteriorated or hydraulic capacity is an issue due to the condition of the sewer.
- **Level 6** Perform further investigations to gather the additional information needed to help define the rehabilitation needs (e.g. geotechnical/geophysical investigations to identify the presence of voids).
- **Level 7** Provide immediate attention (typically local repairs if the sewer has collapsed or failed).

All sewers were assigned a level of rehabilitation of at least Level 1. It is imperative to note that the main rehabilitation levels assigned to the sewers were typically 1 through 5. The rehabilitation levels of 6 and 7 were used as supplemental to the main ratings of 1-5 to either provide more information or to recommend immediate action. For example, a sewer could receive a rehabilitation level of 2-6, meaning maintenance should be performed and that further investigation is warranted to determined the extent of maintenance that needs to be performed.

Table 3 Condition Grades

Condition Grade	Structural Condition	Operational Condition
1	No defects, structural condition of the sewer is like new.	No defects, operational condition of the sewer is like new.
2	Minimal near-term risk of collapse but potential for further deterioration.	Minimal risk of failure - potential for further deterioration; minor impact on operation.
3	Collapse unlikely in the foreseeable future, further deterioration likely.	Failure unlikely in the near future, but moderate impact on operation of system.
4	Collapse of sewer likely in the foreseeable future	Failure likely in foreseeable future; major impact on operation.
5	Sewer is collapsed or collapse imminent in very near future	Operational failure (e.g. blockage) or failure imminent.

RESULTS

Benefits Realized

The Westerly project provided the first thorough inspection and evaluation of the District interceptors and CSOs in the project area. In many cases, this was the first time since construction that the sewers were inspected. Substantial amounts of location, inspection and condition data was gathered and produced throughout the project. Subsequently a thorough understanding of the condition of the system was gained and many benefits were realized during the project. These benefits can be divided into 3 main categories - operational benefits, structural benefits and system knowledge/data benefits.

Operational Benefits

- Identification of Buried Manholes - Throughout the project, inspection crews identified over 100 manholes (out of approximately 800 in the system) that could not be located. These manholes are either buried by debris, are paved over in the roadway, or have been removed at some time prior to District ownership. In several locations, a manhole is close by that allows for access for maintenance, ventilation, etc. However, there are locations where a significant number of sequential manholes are missing and are needed for cleaning, ventilation, access, etc. purposes. For the manholes that are needed, the District will issue a manhole rehabilitation contract to locate, inspect, raise manholes, and if needed perform rehabilitation. The sewer inspections identified the location of these missing manholes, making the subsequent location easier.

- Identification of Sewers Requiring Cleaning - Over 59,000 lineal feet of sewer throughout the project area was identified as requiring cleaning (for more details see Table 4). Over 20,000 lineal feet of sewer could not be inspected because of debris and sedimentation(causing impassable conditions for CCTV equipment and/or dangerous and impassable conditions for the manual walkthrough inspection crews). These sewers require "heavy" cleaning (heavy being defined as more than 1 or 2 passes with a Jet/Vac). As some of this cleaning is beyond the District's equipment and personnel capabilities, the District is preparing to issue a cleaning contract to remove the debris to allow subsequent inspection and evaluation.

- Hydrobrakes - The District operates and maintains several hydrobrakes (structures that store flow in the Northwest Interceptor). The hydrobrakes have accumulated large amounts of sediment behind them, in some cases up to 2 feet of debris - extending back 500 to 1500 feet. This translates amount to a significant volume of debris. A cleaning project will be performed in-house prior to issuance of a cleaning contract. The benefit of cleaning will be to increase the volume of storage during rain events.

- Miscellaneous Benefits - Many minor benefits resulted from the field inspections. In one location a weir was discovered where a 40' sewer segment has been repaired at some time in the past. The weir causes wastewater to pond behind wall and reduces conveyance capacity of the interceptor. Other benefits included the location of isolated blockages, videotapes and photographs of problem areas and others too numerous to mention.

Structural Benefits

- Early Action Projects - Two areas were identified throughout the project as in need of immediate attention. These areas are the Westerly Interceptor near the site of the previous collapse and the Walworth Interceptor underneath Interstate 90. Severe cracks and fractures were noticed in the sewers. In some cases inspectors were able to put a flat metal probe through the sewer wall into the soil behind. As a result, Seismic Tomographic Imaging and soil borings were performed at each of these locations to verify the presence of voids in the surrounding soil. As a result, the District initiated an emergency rehabilitation project (currently underway) that is providing structural relining and grouting in the sewers. The major benefit realized is the avoidance of any catastrophic collapse of these interceptors - the Westerly Interceptor parallels a high-speed railroad track and the Walworth Interceptor is a 10' diameter sewer that runs perpendicularly under an eight-lane highway (Interstate 90) with a depth of 6-10 feet to the crown.

- Recommended Rehabilitation Projects - As a result of the inspections, many locations are recommended for rehabilitation. The benefits realized will be longer life of the sewers, and decreased capital improvement/construction costs (as a result of paying for rehabilitation vs. paying for emergency repairs on collapsed sewers). For more information see the Rehabilitation Recommendation Section later in this report.

System Knowledge/Data Benefits

- Compatible Data Management System Initiated - With any project of this nature and size, enormous volumes of data will be collected. It is important to properly store that data in a manner that is readily and easily available for use. Also, with the nature of technology today, it is necessary for data to be compatible to multiple software uses. For the data collected on this project, multiple detailed Microsoft ACCESS databases were developed to store the manhole and sewer inspection data. This format was chosen because of its compatibility with any GIS platform (such as ARCInfo), infrastructure data management system (such as HANSEN) or data warehouse system (such as ORACLE) that may be used in the future by the District.

- Consistency in Defect Classification - The development of the Manual of Sewer Defect Classification ensures that current and subsequent District sewer inspection projects are performed in a similar manner and sewer defects are identified and encoded correctly and consistently. The consistency in classifying sewer defects would exist regardless or whether the inspections were performed in-house by District crews or by multiple sewer inspection contractors.

- System understanding/Connectivity/Inventory - Throughout the project area, there are many locations where flow direction and connectivity was very confusing. Past top-side reconnaissance and dye testing provided a better understanding of the system, but not a complete and thorough understanding. By performing detailed manhole and sewer inspections throughout the project area, a thorough complete understanding of system connectivity and inventory was gained. This information proves useful for the Westerly CSO Phase II Facilities Plan hydraulic modeling task and future maintenance and rehabilitation work.

- Data Availability - The data collected during the Westerly project has provided, and will continue to provide, useful information for other projects, both District and non-District. The Westerly CSO Phase II Facilities Plan Project is using location and inspection data to assist in the development of the hydraulic model of the system - which will be used to help analyze CSO control alternatives. The data collected will also prove useful when rehabilitation contracts are issued. The contractors will be able to use the inspection date to pinpoint spot repairs, identification of cleaning locations, assistance in manhole location and rehabilitation and so on.

DISCUSSION

Lessons Learned

This project was the largest infrastructure inspection and evaluation project to date for the District . While there were many benefits, many lessons were learned by the consultant team and the District. The lack of consistent basemap/historical information, data management system and institutional restrictions all led to various problems throughout the project. As a result, many steps have taken place to ensure that these problems do not reoccur. Some of the major lessons learned are as follows:

Importance of Data Management System - QA/QC of Data

With any project of this size where enormous volumes of data will be gathered/produced, it is vital to establish a detailed data management system or at least a detailed data management plan. This data management system should be developed prior to the commencement of the inspections. The major lesson learned on Westerly was that the lack of a data management system at the beginning of the project, coupled with a desire to commence field work as soon as possible, resulted in lots of data collected with "no place to go". Throughout the inspection process the data was stored in many ways: field logs, spreadsheet files, miscellaneous reports, etc., and the attempt was made to archive the data into a project database too late in the project schedule. This result was delays in project schedule, QA/QC problems and missing data.

- *The implementation of a good data management system was the most important lesson learned throughout the Westerly District Interceptors - Inspection and Evaluation project. This lesson is probably the most valuable lesson learned that was directly applied to the District's current interceptor inspection and evaluation project.*

Background Information

Lack of consistent maps led to problems early on the project. There were many sources of information regarding the facilities to be inspected. City of Cleveland general sewer maps, orthophoto maps with District interceptor sewers overlaid on top (without CSOs, regulators or any local sewers), and sets of construction plans (although incomplete) were used to assist in understanding the sewer system. However, the different sources of information were inconsistent (i.e. the construction plans did not match the sewer maps) and this led to many problems in determining the actual characteristics of the sewer system.

- *The lesson learned is that the development and assessment of all data available at the beginning of this type of project is vital to the success of the project.*

Manhole Identification System

Prior to the Westerly project, no consistent manhole numbering system has been established across the District service area. The District has had at least two different numbering systems used on past projects and several of the surrounding communities tributary to the District have implemented identification systems for their local sewer systems.

A new manhole numbering system was developed for this project for use throughout the District. The manhole numbering system is length - 15 characters long - and has identifiers for Interceptor Basin, Branch, Manhole Number, Community, Manhole Type and Sewer Type. However, the numbering system was not fully implemented at the beginning of the manhole and sewer inspections. A temporary numbering system was used to allow the contractors to begin their inspections. Problems arose with the use of the temporary numbering system in trying to rectify the temporary manhole numbers and inspection information with their permanent identification numbers in the data management system.

The new manhole numbering system provided a unique identification for each manhole. However, due to the length and complexity of the system, widespread implementation was difficult. The Westerly CSO Phase II hydraulic modelers did not use the numbering system because of the length (the numbering system was greater than 8 characters long). Other problems including the plotting of the numbers on digital sewer maps - the numbers can clutter a map to the point that the sewer cannot be properly identified.

- *The lesson learned from this is that it is important to have a usable manhole numbering system implemented prior to inspections.*

Manhole Inspections

The original intent of the project was to perform top-side inspections of manholes, supplemented by information provided by the pipeline inspection contractors when they entered the sewers to perform the sewer inspections. Complex manhole configuration, numerous manholes with significant depth (greater than 30') and lack of proper illumination led to gaps and incorrect information in the manhole database.

- *The lesson learned from performing the manhole inspections is that a thorough detailed structural inspection can not be achieved from top-side inspection only. There needs to be manual entry on some manholes in order to gain a full understanding of structural problems.*

Defect Identification Guidelines vs. Inspection Contractors Interpretations

Several contractors (2 CCTV, 2 walkthrough and 1 sonar) all worked on the pipe inspections during the Westerly project. The defect identification guidelines did ensure consistency of classification of inspection data. However, different presentation forms were submitted by the contractors, resulting in inconsistency of data submittal formats. While all submittals met the scope of work criteria, some contractors general standards of submittal (photos, inspection logs, even video tape labels) were preferred over the others. The reason for this is that clear requirements were not established at the beginning of the inspections.

- *The lesson learned is that one should establish "exact" or "precise" standards for data submittal, and not leave the format open for contractor's interpretation.*

Recommendations for Rehabilitation

The major deliverable of the Westerly District Interceptors - Inspection and Evaluation Project was the numerous rehabilitation recommendations that were developed. The recommendations were basically broken down into the following categories: sewer cleaning, repair of side sewer connections and stubouts, manhole rehabilitation and the repair of major sewer defects. The rehabilitation recommendations for each category were further broken down by interceptor/CSO basin.

Summaries of preliminary cost estimates for each rehabilitation recommendation category or included in the following tables.

Table 4 Recommended Sewer Cleaning and Sewers Not Inspected

Interceptor Basin	*Sewer Cleaning Length*	*Length Not Inspected*	*Reason(s)***
Low Level Interceptor	5823	716	Poor Access
Northwest Interceptor	27601	0	
Walworth Interceptor	7414	563	Blocked - Submerged
Westerly Interceptor	5857	2362	Poor Access
CSO's & DWO's	12524	17027	Multiple Reasons
Totals	*59219 Ft.*	*20637 Ft.*	

** *Costs not included due to differences/difficulty in estimate of debris volume.*

Table 5 Recommendations for Repair of Side Sewer Connections and Stubouts

Interceptor Basin	*No. of Connections*	*Cost of Rehab ($)*	*Urgency of Rehabilitation*
Low Level Interceptor	0	0	Rehabilitation should be completed prior to the allowance of regular surcharge (storage) in the sewer
Northwest Interceptor	0	0	
Walworth Interceptor	198	$157,000	
Westerly Interceptor	170	$172,000	
CSO's & DWO's	182	$200,000	
Totals	*550*	*$529,000*	

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Table 6 Recommendations for Repair of Manholes

Interceptor Basin	*$$ < 1 Year Urgency*	*1-3 Years Urgency*	*3-5 Years Urgency*
Low Level Interceptor	0	$34,000	0
Northwest Interceptor	0	$750	$20,000
Walworth Interceptor	0	$54,000	0
Westerly Interceptor	0	$24,000	$32,000
CSO's & DWO's	$24,500	$69,500	0
Totals	*$24,500*	*$182,250*	*$52,000*

Table 7 Recommendations for Repair of Major Defects

Interceptor Basin	*$$ < 1 Year*	*$$ 1-3 Years*	*$$ 3-5 Years*	*$$ 5-10 Years*
Low Level Interceptor	$150,000	$638,424	$211,000	$85,000
Northwest Interceptor	$25,000	$711,000	$11,000	0
Walworth Interceptor	$623,600	$1,644,800	$975,800	$4,845
Westerly Interceptor	$1,862,500	$175,530	$216,000	0
CSO's & DWO's	$1,187855	$745,472	$237,852	$1,788
Totals	*$3,848,955*	*$3,915,225*	*$1,651,652*	*$91,633*

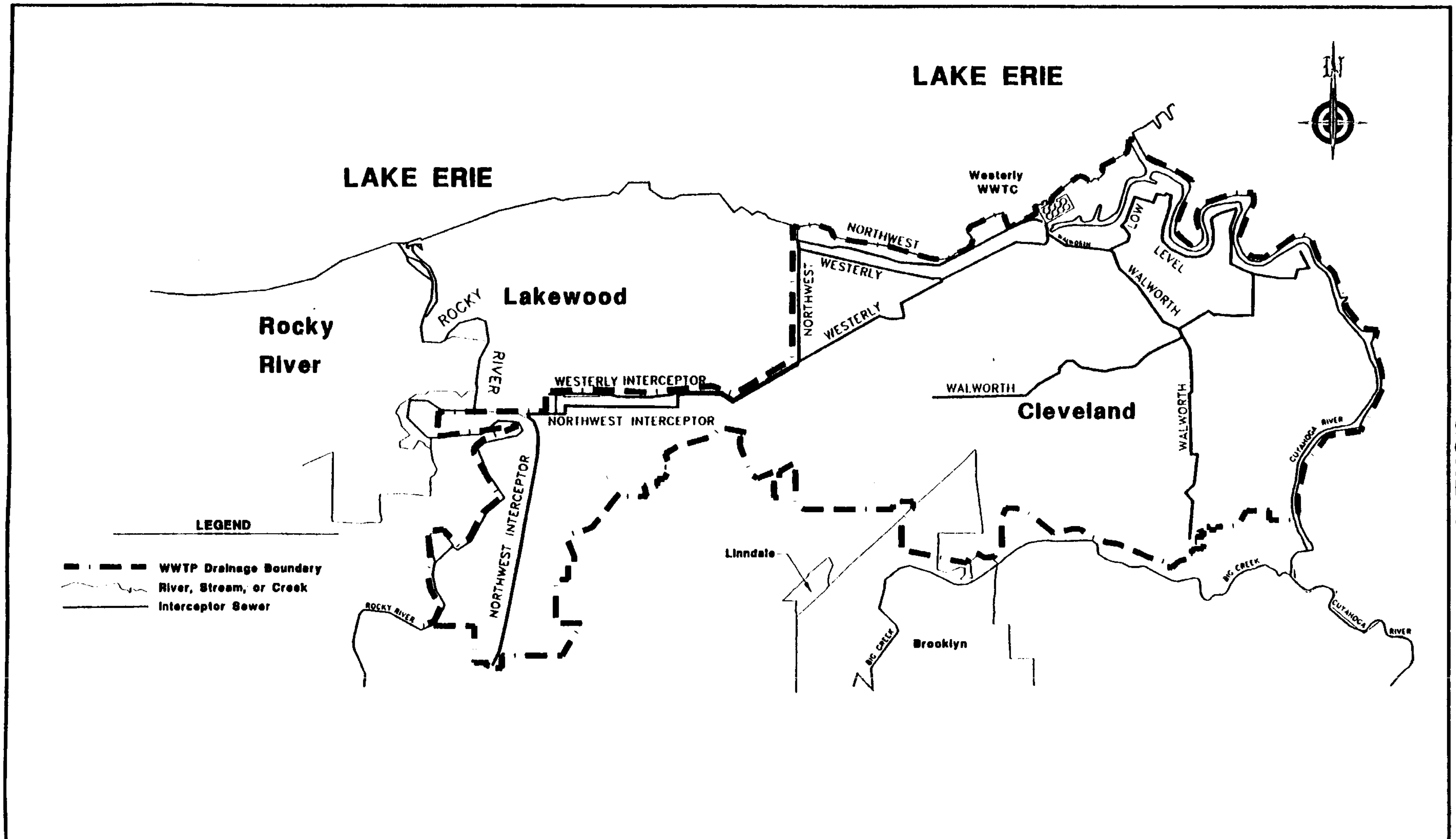
CONCLUSIONS

The Westerly District Interceptors Inspection and Evaluation project provided used condition assessment data for the manholes, interceptor sewers and CSOs and DWOs in the project area. Over $9,000,000 of rehabilitation projects were recommended which, upon completion, will result in a more operationally efficient and structurally sound wastewater collection system. Many operational, structural and system knowledge benefits were gained as well as an education in large scale inspection and evaluation projects and their components, such as data management systems, condition assessment procedures and a thorough understanding of the collection system. *The most important product of the Westerly project may be the lessons learned and application of these lessons learned on subsequent projects.*

As previously stated, there were several tasks that were not performed according to plan on the Westerly project. However, many tasks did go well and these, along with the lessons learned, were applied to the District's current project - Easterly District Interceptors - Inspection and Evaluation Project. The Easterly project is 2 times the size of the Westerly project (Over 550,000 lineal feet of sewers to be inspected versus 225,000 lineal feet in Westerly).

Lessons learned on the Westerly Inspection and Evaluation project that were applied to the current inspection and evaluation project include:

- Full-scale Data Management System established prior to the initiation of the inspections.
- Utilization of one sewer map to provide baseline information (City of Cleveland General Sewer Map) supplement and verify this information with construction plans, community sewer maps and field inspections.
- Detailed standards established on all deliverables from inspection contractors and consultants.
- Establishing a sewer cleaning allowance in the inspection contract to perform some "light" cleaning on the sewers when necessary.
- Increased communication and coordination between the contractors, consultants and other projects working simultaneously in the project area.
- Manhole numbering and preliminary location (on maps) performed prior to field inspections beginning.



WESTERLY DISTRICT INTERCEPTORS - INSPECTION AND EVALUATION PROJECT

FIGURE 1

STORMWATER UTILITIES: KEY COMPONENTS AND ISSUES

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ABSTRACT

Due to increased awareness of the extent of pollution in stormwater runoff, we now recognize the need to manage adverse water quality impacts of stormwater runoff from developing and developed urban areas. Growing numbers of cities and counties are preparing and implementing comprehensive stormwater management programs to prevent and control adverse water quality impacts from stormwater discharges. Establishing a separate department or a separate utility with its own enterprise fund is a viable approach to financing and managing stormwater issues in a sustainable and equitable manner that provides a dedicated, stable, and predictable source of revenues for stormwater controls and best management practices. Stormwater utility revenues fund stormwater management services such as capital improvements, operation and maintenance, and program administration. This paper provides an overview of key components and issues—legal, financial, institutional, and political—in setting up a stormwater utility.

KEY WORDS

Stormwater Utility, Stormwater Management, Finance

INTRODUCTION

Stormwater management in the United States is largely the responsibility of local governments. In the past, communities traditionally financed stormwater improvements from the general fund through property tax revenues and developed their stormwater programs primarily for drainage management or flood control. Increased awareness of the extent of pollution in stormwater runoff is leading local governments to develop more comprehensive stormwater programs—designed to manage both water quantity and water quality impacts of stormwater runoff. Managing the water quality impacts of runoff is an important concern in part because of EPA's stormwater regulations, which require prevention and control of adverse water quality impacts from stormwater discharges. Local governments subject to the stormwater regulations and other communities seeking ways to address local stormwater problems need effective and feasible financing options.

Addressing local stormwater management problems will be costly for many communities, particularly where retrofitting of existing stormwater infrastructure is necessary to manage the water quality impacts of runoff. This paper provides a broad assessment of the need for funding and an overview of stormwater utilities as an effective and feasible option for raising the necessary funds.

FUNDING NEEDS

Estimation of funding needs for stormwater management programs to control the quality of stormwater runoff depends on many different factors. These factors include the characteristics of runoff quantity and quality, the size of the watersheds where projects are being planned, the extent of existing development, the severity of water quality problems, the water quality objectives, and the types of structural controls or best management practices (BMPs) that are being proposed. Recognizing the variability among places, most experts agree that stormwater management programs will be expensive, ranging from tens of thousands of dollars in relatively small places to achieve modest objectives to tens or hundreds of millions of dollars in larger cities with moderate to severe problems.

Several brief examples of the potential magnitude of the costs of stormwater management programs are provided below. These examples are by no means exhaustive and they are not necessarily representative. Nevertheless, they are published estimates of national costs or local examples (for an urban watershed and large city) to demonstrate that experts believe costs will be significant and controversial. Additionally, these examples should demonstrate that a critical task in implementation of effective stormwater management programs is identifying adequate funding sources.

In a recent study for the American Public Works Association (APWA, 1992), James M. Montgomery estimated the capital and operation and maintenance (O&M) costs for large and medium cities to comply with EPA's Phase I stormwater regulations. Capital estimates ranged from $147 million to more than $400 billion, depending on the assumptions about the level of treatment for runoff. Estimates of O&M costs ranged from $1.2 billion to more than half a trillion dollars, again depending on assumptions about level of treatment. Reasonable questions can be raised about the APWA estimates. Some experts suggest that they are too high because advanced treatment has not been contemplated for stormwater runoff. Other critics contend that these estimates were made primarily for political purposes to support opponents of EPA's stormwater regulations who argued that the costs were prohibitive. Regardless, they demonstrate clearly the potential magnitude of funding needs and show that the costs of stormwater management programs will be controversial.

More recently, as part of the 1996 Clean Water Needs Survey (EPA, 1996), EPA modeled the Phase I stormwater needs to inform Congress of the costs of local Phase I stormwater management programs to control pollutants in urban runoff. Approximately 266 Phase I stormwater program permits will be issued covering about 850 municipalities or counties. The modeled Phase I stormwater needs were prepared to estimate the public stormwater management costs that might be eligible under state revolving fund (SRF) loan programs. The SRF-eligible costs include costs for developing and implementing municipal stormwater management programs, including capital costs for structural controls and BMPs. The total modeled Phase I stormwater needs are $7.4 billion. These costs do not include O&M costs, land acquisition costs, permitting costs, costs of developer-financed BMPs, and several other categories of costs that are not SRF-eligible. These CWNS modeled estimates of Phase I stormwater needs, which were subject to peer review prior to their release, are also significant.

In general, better cost estimates can be made for smaller geographic areas because it is possible to take site-specific factors into consideration and make fewer general assumptions. The Wisconsin Department of Natural Resources (WDNR, 1992) has estimated the costs to achieve pollutant reduction objectives for the Menomonee River watershed in Milwaukee, Wisconsin. The Menomonee River watershed is 136 square miles, is 60 percent urban, and contains 18 municipalities and parts of four counties. To meet ambient water quality standards, programs are needed to reduce sediment by 50 percent, phosphorus by 50 to 70 percent, and lead by 35 to 70 percent. The corresponding cost estimates for "segment" controls for existing areas of development range from $94 million to $184 million.

Finally, in Indianapolis, Indiana, a Mayor's blue ribbon panel estimated the costs to rehabilitate stormwater infrastructure at $283 million. The infrastructure includes 1,750 miles of storm sewers, more than 1,000 outfalls, more than 50 miles of levees, and a number of regional detention ponds. The panel's estimate represents a significant cost simply to meet generally accepted engineering standards for stormwater conveyance and flood control. The panel did not estimate costs for programs to manage pollutants in runoff, such as implementation of BMPs to meet water quality objectives..

THE STORMWATER UTILITY APPROACH

Financing stormwater management through a public utility approach is an innovative alternative to the traditional financing of local stormwater programs by property tax revenues. Public resistance to property tax increases has limited the ability of local governments to raise additional funds for stormwater management or other environmental programs through the property tax. After several communities successfully implemented a utility approach to finance stormwater management in the 1970s—most notably, Bellevue, Washington, and Boulder, Colorado—stormwater utilities became a viable financing mechanism for other communities. Currently, several hundred communities across the country have instituted stormwater utilities.

A stormwater utility is a public utility established to provide stormwater management services. Stormwater utilities, like other utilities, rely on dedicated user charges related to the level of service provided. These user charges are usually based on the amount of impervious area (paved surfaces and structures) on a property (i.e., a proxy for the estimated amount of runoff discharged from a property) and are typically paid by property owners. Impervious area is generally defined as surfaces that either prevent or retard infiltration of stormwater into the ground. Dedicated means that the revenues are placed and managed in a separate enterprise fund, which can only be used to finance stormwater management.

Most stormwater utilities are administered under public works departments or local departments of utilities that also provide wastewater or water services. Stormwater utilities have been established for both large and small service areas, with populations ranging from several thousand to over 500,000 persons and ranging in size from several to over 500 square miles. While most utilities serve a single jurisdiction, several serve multiple jurisdictions and a few serve the unincorporated areas of a county.

Experience with stormwater utilities has shown that they are capable of generating substantial revenues and providing financial self-sufficiency for local stormwater management programs at relatively nominal charges. Typical monthly charges for residential users range from $2 to around $6 per month. Nonresidential property owners typically pay more because their property is generally larger and developed more intensively.

The stormwater utility concept offers several advantages over the traditional financing by property tax revenues. Stormwater utilities provide a more secure revenue source for local stormwater management than property taxes. Because property tax revenues usually go into the general fund to finance a wide variety of local services, many programs compete for funding from such revenues. Without a dedicated revenue source, stormwater programs often do not gain priority in the local budget process and thus lack adequate funding. In addition, stormwater utilities allow a closer relationship between the charges and services provided than property taxes.

Stormwater utilities offer three major advantages over financing local stormwater programs from the general fund through property tax revenues. These three major advantages are that a stormwater utility:

1) Provides a dedicated, stable, and predictable source of funds for all facets of local stormwater management programs (capital improvements, operation and maintenance, and program administration);

2) Raises funds through charges based on a user's contribution to local stormwater runoff problems so a utility approach is often seen as more equitable to rate payers or the public; and

3) Provides an institutional mechanism to incorporate incentives (e.g., reduced charges) for implementation of on-site stormwater management.

KEY COMPONENTS AND ISSUES IN SETTING UP A STORMWATER UTILITY

To develop and implement a stormwater utility, each community must address a variety of legal, financial, institutional, and political issues. Key components and issues—legal, financial, institutional, and political—in setting up a stormwater utility (USEPA, 1994b) are summarized below.

Legal components

A combination of state enabling legislation and local ordinances is generally required to establish a stormwater utility, although the exact legal requirements vary according to the laws and precedents in each state. The major legal components in setting up a stormwater utility are enacting state enabling legislation, adopting a local stormwater utility ordinance, and avoiding legal challenges.

Enacting state enabling legislation

State enabling legislation must authorize the formation of local stormwater utilities. Many states already have such legislation either in general form, authorizing local governments to form public utilities, or specifically authorizing stormwater utilities.

Adopting a stormwater utility ordinance

Stormwater utilities are typically created by the adoption of a local ordinance. To assure flexibility in reviewing and adjusting stormwater program goals as well as rates charged by a utility, communities often adopt two ordinances. The first ordinance establishes the community's operational authority and stormwater management program and the second ordinance establishes the stormwater utility and its rate structure. An advantage of this approach is that when rates require adjustment, the ordinance authorizing the local stormwater program remains intact.

Avoiding legal challenges

To anticipate and avoid legal challenges, utility planners need an in-depth understanding of legal issues associated with stormwater utilities. Several stormwater utilities across the country have been challenged legally. Most legal challenges are related to the legality of imposing utility charges or the specifics of the rate structure. Legal challenges are often based on the grounds that a utility service charge is really a tax or that previously tax-exempt entities, such as churches or hospitals, also should be exempt from stormwater utility charges. To avoid legal challenges, it is important to distinguish the utility charge from the property tax by clearly establishing a direct relationship between the utility charge and stormwater management services provided by a utility.

Financial components

The ability of the utility approach to provide a dedicated, stable, and predictable source of revenue to finance local stormwater management services is a primary advantage of establishing a utility. When designed properly, a stormwater utility rate structure allocates costs among users according to services received. The major financial components in setting up a stormwater utility are:

- Estimating revenue requirements,
- Determining the rate base, and
- Developing the rate structure.

Estimating revenue requirements

Many stormwater utilities rely almost entirely on revenues from utility charges. To develop a rate structure that raises sufficient revenues to cover the full costs of a local stormwater program, utility planners must estimate the total costs of desired stormwater management services. Often, financial, economic, and engineering analyses are necessary to determine revenue requirements for the capital costs of constructing needed stormwater management facilities. Cost estimation also involves long-range planning for construction of needed stormwater management facilities.

Determining the rate base

In determining the rate base, utility planners must decide who will pay the utility charges and whether to allow any exemptions. Ratepayers are typically property owners that contribute stormwater runoff. Thus, many utilities include in their rate base only developed property, which usually contains impervious area. Although publicly owned or nonprofit properties are normally exempt from the property tax, stormwater utilities often include such properties in their rate base. This practice has withstood legal challenge—most notably in

Louisville and Jefferson County, Kentucky—where the court determined that utility charges were a fee, not a tax.

Developing the rate structure

Developing an appropriate rate structure is critical to establishing an effective stormwater utility. When designed properly, the rate structure allocates costs among users according to services received. The three basic elements of developing a stormwater utility rate structure are:

- Determining the basis for charges,
- Determining the billing unit, and
- Setting the rate.

Stormwater utility charges are usually based on an estimate of the amount of stormwater runoff contributed by a property. This contribution may be estimated, for example, by total impervious area on a parcel or a ratio of impervious area to total property area. The rate structure can also be tied to the intensity of development (e.g., as reflected by land use categories such as residential, commercial, or industrial).

Using impervious area as the basis for charges allows a utility to develop a uniform billing unit based on the amount of impervious area for the typical residential property and use that unit to calculate charges for other types of property. A common billing unit is the use of equivalent residential or runoff units (ERUs). An ERU represents the average impervious area associated with residential parcels (e.g., single family homes) in the utility service area. A utility develops an ERU by estimating the total impervious area of residential parcels and dividing this amount by the total number of residential parcels. These calculations usually are based on a statistical sample of residential parcels in the service area.

With the ERU approach, the billing unit represents an estimate of the impervious area associated with the average residential property. For example, an ERU may represent 2,500 square feet. The billing unit for all residential properties is one ERU. For parcels in other land use categories (e.g., commercial, industrial), the runoff potential is based on the number of ERUs associated with the impervious area of each parcel. The amount of impervious area on a nonresidential property is divided by the ERU square footage to calculate the number of billing units (ERUs) for each nonresidential parcel in the rate base.

Utilities that use ERUs as the billing unit generally set the rate per ERU. If a utility charges a monthly rate of $3.00 per ERU, for example, then all owners of residential properties, which represent one ERU, would pay a $3.00 monthly utility charge. Utilities using ERUs generally calculate stormwater utility charges for nonresidential property owners individually by calculating the number of ERUs associated with their nonresidential parcel and multiplying by the rate. A typical billing algorithm for nonresidential properties is: (total impervious area/ERU square footage) x (rate per ERU). Using this billing algorithm, for example, the monthly utility charge for a nonresidential property with an impervious area of 10,000 square feet would be $12.00, where the ERU represents 2,500 square feet.

Although the most common type of stormwater utility charge is based on the amount, or square footage, of impervious area on a parcel, other indicators or proxies for the actual volume of stormwater runoff from a property are used by some utilities. Other bases for stormwater utility charges include the area and proportion of impervious cover on a parcel, the intensity of development, and the type of land use. Recently, a few utilities have experimented with actual estimates of the volume of runoff or some estimate of the concentration of pollutants in runoff as the basis for charges. Examples of more complex stormwater utility rate structures are presented in the case studies below.

Experience with stormwater utilities shows that they are capable of providing financial self-sufficiency for local stormwater management programs at relatively nominal charges. Single family residential charges for most stormwater utilities currently range from $2.00 to around $6.00 per month. Some stormwater utilities establish initial rates at lower levels and schedule rate increases as the utility provides an increased level of stormwater management services. Communities may budget for contributions from the general fund to the utility over a certain time period to allow for a gradual transition to a fully established utility.

Institutional components

Institutional issues are also important to successful creation and implementation of a stormwater utility. Selected institutional issues discussed below are the appropriate administrative structure for local stormwater management, the role of public education and involvement, and credits as economic incentives for on-site stormwater management.

Determining an administrative structure for stormwater management

Most stormwater utilities are administered under public works departments or local departments of utilities that also provide wastewater or water services. To determine the most appropriate administrative structure for providing stormwater management services, each community must examine its stormwater management goals and specific functions (e.g., administration, planning, design and engineering, construction, operation and maintenance, regulation and enforcement, and billing and collection of utility charges) performed to provide those services.

Implementing public education and involvement programs

Public support is critical to establishing a successful stormwater utility because such support ensures that a utility will have adequate financial resources to perform stormwater management activities. Education and involvement programs for local elected officials and the general public help develop a clear understanding of the need for and expected benefits from a utility's activities.

Credits as economic incentives for on-site stormwater management

Stormwater utilities provide an institutional mechanism to incorporate incentives for implementation of on-site stormwater management through credits or reduced user charges. Providing such incentives creates greater flexibility by allowing each user to chose the least-cost option—paying the stormwater utility charge or implementing on-site stormwater management. A recent paper (Doll, Scodari, and Lindsey, 1998) provides examples of stormwater utilities with credits for on-site stormwater management, including credits for peak runoff controls, implementation of water quality BMPs, and proper maintenance of on-site stormwater facilities. Also discussed are issues associated with establishing credits as economic incentives to encourage prevention or reduction of stormwater runoff problems. As economic incentives, credits must be sufficient to induce changes in behavior; however, their impact on total utility revenues must be examined carefully.

Political components

Finally, political support is important to establishing a utility rate structure. The nature of local government is that key players in utility design and implementation are seldom the key players in local politics. In designing a utility rate structure, utility planners can attempt to minimize controversy by gaining the support of local elected officials.

As an example, in the City of Indianapolis, Indiana, considerable controversy arose over a proposed stormwater utility. A credit system was proposed to help overcome general opposition to new charges or taxes. Through a credit system, utility planners and local elected officials attempted to make the proposed stormwater utility charges more equitable and acceptable politically. The credit system in the final draft ordinance (Proposal No. 657, 1997) was a relatively complex approach to provide a reduction in stormwater user fees for nonresidential properties based on certain conditions. The draft ordinance outlined a two-tiered credit based on watershed area as well as the size of the on-site detention/retention basin. Efforts to establish a credit system for on-site detention/retention addressed concerns of nonresidential property owners and generally increased the perceived fairness of the proposed rate structure. It is now clear that inclusion of a credit system was not sufficient to ensure adoption of the stormwater utility and overcome other objections.

Despite significant efforts to gain political acceptance, the utility proposal was withdrawn pending completion of more detailed planning studies.

CASE STUDIES OF SELECTED STORMWATER UTILITIES

This section presents case studies of selected stormwater utilities. The selected utilities are Austin, Texas; Bellevue, Washington, and Boulder, Colorado (USEPA, 1994a).

Austin, Texas

In September 1982, the Austin City Council approved the first drainage fee charged on Austin utility bills. Revenues from the drainage fee were initially used to supplement general funds used for drainage-related activities. Historically, the drainage fee provided support for drainage-related activities of several city agencies, including the Department of Public Works and Transportation, Environmental and Conservation Services Department, and the Parks and Recreation Department. In September 1989, the City Council dedicated all drainage fee revenues to drainage-related activities. In September 1990, the City Council created the Drainage Fund as a dedicated account for managing the receipt and expenditure of drainage fee revenues. City Council action in September 1991 increased Austin's drainage fees from $1.30 per month for residential property and $14.04 per acre per month for commercial and industrial property to $3.32 per month and $35.83 per acre per month, respectively. These increases were approved to begin developing and implementing solutions to the water quality problems of Austin's urban watersheds and Town Lake.

When the Drainage Utility (DU) was established in November 1991, drainage fee revenues were fully dedicated to the Drainage Utility Fund. The drainage fee is assessed to all electric, water, or wastewater customers (except for properties owned by the state, county, and school districts) within the incorporated area of the city. In 1993, the drainage fee was $3.82 per household per month for residential customers and $41.23 per acre per month for commercial and industrial customers. The utility generated approximately $5.4 million in annual revenue from commercial and industrial customers, and $9.0 million in annual revenue from households, for total annual revenues of $14.4 million in 1993.

Most of the city's stormwater programs are funded by DU. Additional financing for some aspects of stormwater management comes from other sources, including annual storm sewer discharge permit fees, development fees, and federal grant funding for selected projects (e.g., development of innovative control structures for retrofitting high density urban core areas). Review of drainage or flood control plans by the Planning and Development Department is not funded by DU.

The urban retrofit program established by Austin's Urban Watersheds Ordinance has an estimated capital cost of $250 million over a 25-year period. Because this represented a substantial increase in capital expenditures, DU planned to issue revenue bonds to finance the construction and acquisition costs for drainage improvements under the urban retrofit program. The bonds would be repaid by drainage fee revenues.

Bellevue, Washington

When first established in 1974, the City of Bellevue's Storm and Surface Water Utility (SSWU) focused on examining various solutions to control flooding and preserve waterways. The utility selected an "open stream concept" using streams as the main conveyance system for stormwater runoff. This system uses regional, in-stream flood control facilities to attenuate peak flows for older development. The utility also manages the municipal storm drainage system. In addition, regulations require developers to provide erosion and sedimentation controls at all construction sites and on-site stormwater controls for new development. With successful flood control systems in place, the focus shifted to water quality controls including requirements mandated by the federal Clean Water Act. For the most part, SSWU's comprehensive effort to solve stormwater quality problems is preventive in nature, but the utility also recognizes the need for retrofitting and new capital improvements for treatment.

The City of Bellevue decided that the most equitable system of drainage service charges would be to base them on the estimated amount of runoff individual properties contribute to the surface water system. All properties are classified according to their intensity of development. Each classification is assigned a rate (per 2,000 square feet of property area), with rates in 1993 as follows: undeveloped ($0.17), light development ($0.99), moderate development ($1.23), heavy development ($1.83), and very heavy development ($2.46). Wetlands are also a class, however, wetlands are not charged due to their value in water quantity and quality control. The classification combined with the total square footage of the property determines the service charge, which is billed every two months.

Revenues grew slowly until rates were raised to fund the adopted Capital Improvement Program, which was initiated by issuance of $10 million of revenue bonds. Three major rate increases occurred in 1980 (70 percent), 1982 (90 percent), and 1986 (35 percent), and subsequent rate increases have remained in the single-digit category largely to cover inflation. Although the majority of SSWU revenue is from service charges, other revenue sources include clearing and grading permit fees, general facilities charges, and interest on fund accounts. Revenues from the utility service charges and these other sources cover the full costs of Bellevue's storm and surface water management program.

Single family customers made up 92 percent of the 24,000 accounts and contributed 45 percent of the revenue in 1993. An average single family household paid $16.44 every two months ($98 per year) for 10,000-12,000 square feet of property with a typical home. Tax-exempt properties are not exempt from the utility charges (Washington State highways and Bellevue streets are SSWU's two biggest ratepayers).

Boulder, Colorado

The Boulder Storm Water and Flood Management Utility was created in 1973 by Boulder City Ordinance No. 4749, which is codified in Title 11, Chapter 5 of Boulder's City Code. It serves an area of approximately 40 square miles and was created in the Utilities Division of the city's Department of Public Works and is under the control of the City Manager. Boulder's utility has no governing structure or officers, although it does receive input and guidance from the Utilities Advisory Board. The utility primarily serves as a mechanism to manage dedicated revenues from stormwater and flood management fees within the Utilities Division of the Department of Public Works. During the late 1980s, Boulder developed a "Comprehensive Drainage Utility Master Plan" (CDUMP) to address flooding and stormwater issues. In 1989, Boulder's Storm Water Quality Program was developed as a component of CDUMP to address water quality issues related to stormwater runoff.

Activities conducted by Boulder's Storm Water and Flood Management Utility are financed by user fees. All owners of developed property in the city must pay a monthly stormwater and flood management fee, which is determined according to the anticipated use of drainage facilities. Undeveloped parcels are exempt from the fee. The fee is calculated according to the following formulas:

> Fee = $4.40 x (parcel runoff coefficient/0.43) x (property area/7,000 square feet)
>
> Parcel runoff coefficient = ((0.9 x impervious square footage) + (0.2 x pervious square footage))/total square footage

The average residential charge is $4.40 per month (for < 15,000 square feet). It can range up to $5.40 (for 15 to 30,000 square feet) or $6.60 (for > 30,000 square feet). The stormwater and flood management fee is collected on the city's water and wastewater utility bills.

Annual revenues for 1993 from the stormwater and flood management fees were $2.5 million. The Storm Water and Flood Management Utility holds all fee revenues in a dedicated account and may make expenditures only for the following purposes: 1) development review, administration, stormwater quality, inspection, construction, installation, repair, maintenance, improvement, replacement, and reconstruction of drainage facilities in the city, and all other facilities necessary to handle stormwater runoff and floods in the city; purchase of land or easements that may be required to implement stormwater and flood management in the city; and repayment of any revenue bonds issued by the city to finance any of the above activities.

Boulder has issued a revenue bond, backed by the stormwater and flood management fees, to finance some of the utility's capital improvement projects. The utility spends about $1.3 million annually on capital improvement projects.

In addition to the stormwater and flood management fee, the Boulder utility charges a developer fee for the development of previously undeveloped property, annexation of developed property, and changes or additions to developed property. This developer fee is based on the square footage of the extended service area, or the utility may also allow a developer to build their own approved system extensions. Revenues from developer fees are used solely for the purpose of capital improvements, reconstructions, or expansions. Annual revenues for 1993 from these developer fees were $75,000.

CONCLUSION

Stormwater utilities are now well established as an effective and feasible financing option for raising the necessary funds for local stormwater management programs. Clearly, there is a large funding need for stormwater management programs to prevent and control the adverse water quality impacts of stormwater runoff in our nation's urban and urbanizing areas. Most of the key components and issues—legal, financial, institutional, and political—in setting up a stormwater utility are manageable. The critical component at the local level in setting up a stormwater utility is often political, where local elected officials and the public must make difficult choices among many needed local services. Once established, however, a stormwater utility provides a dedicated revenue source for stormwater management and is often seen as more equitable to rate payers or the public because charges are based on each user's contribution to local stormwater runoff problems. Stormwater utilities can generate substantial revenues and provide financial self-sufficiency for local stormwater management programs at relatively nominal charges.

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WET WEATHER FLOW CONTROL PLANNING FOR GREAT LAKES CLEANUP

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ABSTRACT

Impairments to beneficial uses such as recreation, sediment dwelling organisms, and fish and wildlife habitats have been, in part, caused by discharges from sewage treatment plants (STPs), combined sewer overflows (CSOs) and stormwater. Municipalities in areas identified by the International Joint Commission as Areas of Concern (AOCs) are addressing these problems by conducting Pollution Prevention and Control Plans (PPCPs) and carrying out the recommended implementation strategy. Environment Canada's Great Lakes 2000 Cleanup Fund and the Ontario Ministry of the Environment have provided funding and technical assistance to conduct these PPCPs. Joint federal/provincial/municipal projects are also underway to develop and demonstrate lower cost technologies as alternatives to conventional options that are typically recommended in the PPCPs.

This paper highlights the findings of PPCPs conducted in the various AOCs and their status of implementation. In addition, demonstration projects related to low-cost innovative technologies aimed at reducing the costs of implementing the PPCPs are described.

KEYWORDS: pollution control planning, pollution prevention, stormwater management, CSOs, Great Lakes, Areas of Concern

INTRODUCTION

During the later part of the 1980s, Pollution Control Plans (PCPs) were carried out by many Ontario municipalities under Ontario's Beaches Improvement Program to develop cost-effective solutions for controlling the impacts of point sources (from STPs and industries), and non-point sources (CSOs and stormwater). The planning process followed is a means of integrating technical concerns and public input to arrive at cost-effective solutions that satisfy social, environmental and economic goals. Since 1990, greater emphasis has been placed on prevention aspects in addition to control, with a change in the name of the studies to Pollution Prevention and Control Plans (PPCPs). The names are used interchangeably in this paper.

The steps generally used in a PPCP are :

1. Assess loadings and relative receiving water quality impacts of the municipal effluents.
2. Evaluate the most appropriate pollution prevention and abatement measures for the STPs CSOs and stormwater discharges.
3. Conduct the study in conformity with the Class Environmental Assessment for Municipal Water and Wastewater Projects under the provincial Environmental Assessment Act.
4. Develop the Pollution Prevention and Control Plan to optimize environmental objectives and costs.

POLLUTION PREVENTION AND CONTROL PLANNING IN AOCs

As shown in Table 1, PPCPs have been completed in four AOCs while three are underway. The PPCPs for Belleville, Trenton and Severn Sound municipalities deal with stormwater only since there are no CSOs in these municipalities. STP effluents are of concern for Sarnia, Cornwall, Thunder Bay and Windsor, since these municipalities provide only a primary treatment level for their sewage. Pollution

Control Plans have been completed prior to the availability of federal funding for a few other municipalities with CSO problems in AOCs, , i.e. Hamilton-Wentworth in the Hamilton Harbour AOC, and Toronto area municipalities in the Toronto Waterfront AOC.

TABLE 1: POLLUTION PREVENTION AND CONTROL PLANS IN AOCs

Municipality/Area of Concern	**Municipal Effluents addressed in PCP**	**Status**
Sarnia/St. Clair River	CSO, SW, STP	Completed 1993
Cornwall/St. Lawrence River	CSO, SW, STP	Completed 1995
Thunder Bay/Lake Superior	CSO, SW, STP	Completed 1996
Windsor/Detroit River	CSO, SW, STP	Underway
Belleville/Bay of Quinte	SW	Completed 1996
Trenton/Bay of Quinte	SW	Underway
Severn Sound municipalities	SW	Underway

Beneficial use impairment attributed to municipal effluents include:

- degradation of benthos due to accumulation of heavy metals and organic chemicals in bottom sediments
- degradation of aesthetics caused by algae and floatables
- negative impact to fish and wildlife habitat (e.g. fish advisories, and poor aquatic habitat)
- limitations on recreational use of the receiving waters (e.g. beach postings)

City Of Sarnia Pollution Control Plan - St. Clair River AOC

The City of Sarnia (population: 74,200) is located at the southern edge of Lake Huron, on the shore of the St. Clair River. The city lies on the border between Ontario and the State of Michigan in the U.S.

Beneficial use impairments attributed to municipal effluents include degradation of benthos, limitations on recreational use and negative impact on fish and wildlife habitat. Restrictions on consumption of fish and wildlife exist because of high levels of mercury and polychlorinated biphenyls (PCBs) in the fish and wildlife.

As shown in Table 2, the STP contributes the greatest amount of suspended solids (SS), biological oxygen demand (BOD), phosphorus (P) and bacteria to the St. Clair River. For the local Sarnia waterfront, CSOs are the main source of bacterial pollution to the waterfront during wet weather. During wet weather, stormwater runoff is the main source of SS to the St. Clair R. The amount of P in stormwater is similar to that from the STP under wet weather conditions.

TABLE 2 : POLLUTANT LOADINGS - CITY OF SARNIA

	TSS	TP	BOD	Bacteria, (bMPN/1000 mL)
STP (dry weather)	263,300	6,800	526,600	54×10^6
STP (wet weather)	66,060	1,700	132,100	12×10^6
SW	258,300	1,200	23,280	1×10^6
CSO	33,370	625	9,900	2×10^6

Note: Loadings represent period from April 1 to October 31. Units: kg/rainfall season

The PCP recommended (1) upgrading of the primary STP to secondary treatment standard and year-round disinfection, (2) provision of more settling capacity (for the interim period till the secondary STP is built) to fully treat all flows and hence, eliminate bypassing of flows, (3) construction of 4 CSO tanks to achieve a 90% level of volumetric runoff control), (4) collection of stormwater flows into an interceptor pipe and conveyance to a stormwater pond.

The total cost of implementing the recommendations from the PCP was estimated at $48.5 million (1993$) STP upgrade cost - $29.2 million, 4 CSO storage tanks - $12.7 million)

Implementation of the recommendations is underway. In 1996, the City of Sarnia constructed one CSO storage tank at a cost of $4.73 million (funded under the joint Canada-Ontario Municipal Infrastructure Program). This tank was designed to handle the volume requirements of two-originally proposed tanks, realizing a cost saving of several hundred thousand dollars. The pre-design of the secondary STP has been completed. Detailed design and construction is expected pending the availability of sufficient funding resources.

Cornwall Pollution Control Plan - St. Lawrence AOC

The City of Cornwall,(population: approximately 47,000) is situated on the banks of the St. Lawrence River. The beneficial use impairment of the St. Lawrence AOC associated with municipal effluents as well as other point and non-point source discharges include impact to fish and wildlife (consumption restrictions, population degradation, deformities, tumours and habitat losses); beach closings, degradation of benthic communities and drinking water restrictions.

As shown in Table 3, the STP is the main source of pollutants during dry and wet weather. During wet weather, the TSS loadings from CSOs and stormwater are of the same order of magnitude as that from the STP.

TABLE 3 : POLLUTANT LOADINGS FROM CITY OF CORNWALL

	TSS	TP	BOD	Bacteria org/hr - fecal coliform)
STP (dry weather)	169,270	3,070	482,130	5.2×10^9
STP (wet weather)	66,770	2,225	69,550	5.1×10^5
SW	45,880	237	6,080	2.2×10^4
CSO	51,710	286	4,270	3.9×10^5

Note: Loadings represent period from April 1 to October 31. Units: kg/rainfall season

From the PCP, stormwater impacts would be more pronounced in the tributary drains that receive the stormwater rather than the St. Lawrence River itself. For example, one of these drains (the South Branch of the Raisin River) has a low baseflow. Hence, the additional stormwater with its relatively higher concentration of contaminants (in particular, total phosphorus, iron, zinc, mercury and fecal coliform) was likely contributing to reported impairment in water quality.

The PCP recommendations were prioritized as follows: implement CSO control measures followed by stormwater measures and then finally, upgrade the STP to secondary treatment. This prioritization reflected the need to first eliminate uncontrolled discharge of untreated sanitary wastes to the St. Lawrence River from the existing CSOs, thereby improving the quality of the nearshore waters. The stormwater measures would improve the water quality and aquatic habitats particularly in the tributary drains (South Raisin River and Grays Creek). Finally, the STP upgrade would further improve the water quality of the St. Lawrence River.

Recommendations for CSO control included (1) provision of a 17,500 m^3 underground storage tank and consideration of first flush storage and satellite high rate treatment to reduce the cost of storage, (2) continuation of ongoing program of on-lot flow reduction especially in subcatchments with high wet weather infiltration/inflow (I/I), (3) continuation of real time control with the Brookdale gate, (4) continuation of the City's water conservation strategy and (5) completion of sewer separation projects planned for selected subcatchments.

Recommendations for SW abatement included (1) continuation of existing stormwater best management practices (e.g. street sweeping and catchbasin cleaning, (2) enhancement of vegetation and flow distribution in the Fly Creek stormwater pond to improve its water quality function, (3) completion of a detailed feasibility study for stormwater quality control wet ponds in existing developed areas, (4) adoption of a comprehensive Stormwater Quality Discharge Control program for new development areas, (5) implementation of stormwater ponds wherever feasible for existing developed areas.

Recommendations for improving sewage treatment included (1) conduct a pilot testing program of secondary treatment options, (2) develop a detailed facility plan to refine capital cost estimates of secondary treatment options.

The total cost of implementing the recommendations from the Cornwall PCP was estimated at $44.3 million (1993$) (CSO storage tank - $11.0 million, STP upgrade - $31 million). Since the PCP was completed, an environmental study report identifying options for upgrading the Fly Creek Stormwater pond for quality control has been undertaken.

Thunder Bay Pollution Prevention and Control Plan - Thunder Bay AOC

The City of Thunder Bay (population: approximately 114,000) is situated on the west shore of Lake Superior. There are seven water courses in the study area. All of these and Lake Superior are considered important fisheries habitat or pathways to spawning grounds. Table 4 presents the pollutant loadings from the city's sewers. The results of the receiving water impact study of the PCP that CSOs and stormwater discharges were not significant sources of pollutant loadings in the area.

TABLE 4: POLLUTANT LOADINGS FROM CITY OF THUNDER BAY

	TSS	TP	BOD
STP(dry weather)	1,352,400	31,750	2,381,400
STP(wet weather)	67,620	1,566	119,070
SW	423,080	1,030	61,360
CSO	6,090	50	1,380

Note: Annual Loadings; Wet weather 5% of the time; Units: kg/year

The PCP study found that the objectives could be achieved by replacement of many of the CSO regulators and other O&M type actions. The overall recommendations of the PCP was set out in a 2 stage process (a short term PPCP and a long term PPCP.

The cost of the short term PPCP was estimated at $3.9 million. With the short term CSO control recommendations of replacement of 12 regulators and other O&M type actions, the CSO volume criteria of 90% volumetric runoff control could be met. Recommendations for the STP included conducting a pilot study to investigate treatment technologies for secondary upgrade to the STP and improving digester mixing. Pollution prevention measures recommended increasing the scope of routine catch basin cleaning/street sweeping, and downspout disconnect and public education programs.

Total estimated cost of the long term PPCP recommendations for the collection system was $15.5 million (excluding the STP upgrade). The long-term PPCP includes collection system management in the context of controlling and managing excess wet weather flows, considerations for future development and elimination of basement flooding. Recommendations for the collection system included provision of a 8760 m^3 storage tank (est. cost $5.4 million), new storm sewer construction and providing an additional pumping station. The estimated $30 million upgrade of the STP to secondary treatment would be pending the results of the pilot study which was initiated in 1996.

Windsor Riverfront Pollution Control Planning Study

This study consists of three phases. The Phase I work (completed in 1995) determined the quantity and quality of the municipal effluents discharged under wet and dry weather conditions to the Detroit River. The pollutant loadings are shown in Table 5. The study also estimated the impact of the municipal effluents on the river. The City of Windsor is served principally by combined sewers, with practically no separated systems. Storm relief sewers have been installed in some areas to relieve flooding in the combined sewer system - these are considered to be CSOs.

TABLE 5: POLLUTANT LOADINGS FROM THE CITY OF WINDSOR

	TSS	TP	BOD
STP	812,600	20,000	1,253,000
STP Bypass	55,700	1,000	86,000
Storm Relief	640,900	8,000	131,000
CSO	885,000	8,000	279,000
Industrial	37,500	-	-

Note: Annual Loadings; Units: kg/year

It is worthwhile to note that the above loadings account for 1% to 5% of the contaminant loadings to the river in this area - the remainder being discharged from the Detroit area.

Phase 1 determined that Windsor's municipal effluents had minimal impact on the Detroit River. Since no bathing beaches are present in the immediate areas of the discharges, recreational use is not impaired. Consequently, the objective adopted for the study was to meet the minimum requirements of the MOE CSO policy - that is, that 90% of the wet weather flow from the CSO system is to receive at least primary treatment. Phase II of the study, completed in 1997, evaluated options for meeting this CSO objective.

It is proposed that a short term program be initiated to address operational concerns, pollution prevention and non-structural control measures. Long term control measures being considered include 1) construction of storage facilities to detain wet weather flows for eventual treatment at the West Windsor STP, and 2) satellite treatment using retention treatment basins (or some other high rate treatment method such as vortex separation).

Because of site constraints that will limit the use of high rate treatment at some of the CSO locations, only part of the system can be controlled using this method. Control costs for storage alone, using underground tunnel storage and conveyance, are $61 million, rising to $148 million with the inclusion of storm relief flows. Control costs for use of retention treatment basins for part of the area, along with a smaller storage tunnel are $48 million, rising to $93 million with the inclusion of storm relief flows. All options include an increase in primary treatment plant capacity to increase the dewatering rate for the sludge from the storage tanks.

Phase III, underway in 1998, will present long term control options to the public, including the Remedial Action Plan Public Advisory Committee, to input into the preferred option.

City of Belleville Pollution Control Plan - Bay of Quinte Area of Concern

Bacteriological contamination of surface waters in the Bay of Quinte has impaired beneficial use related to recreational activities in the Bay. The bacterial contamination is attributed primarily to stormwater runoff.

The PCP for the City of Belleville quantified and located the sources of bacterial contamination under both dry and wet weather. Under dry weather, some of the storm outfalls are occasionally contaminated.

However, the level of contamination is quite variable. For those sewers that were consistently contaminated, the source was identified and the problem tributary lines were isolated. Sanitary cross-connections and/or sewer leakages were suspected to be the cause of bacterial contamination in these lines

During wet weather, bacterial contamination occurs in the receiving waters of the Moira River, increasing by approximately an order of magnitude compared to dry weather periods. These elevated bacterial concentrations lead to contamination of east Bayshore of the Bay of Quinte within the City of Belleville and a beach (Riverside Beach) within the Moira River.

The high levels of bacteria are attributed to washoff of bacteria-laden sediment from urban surfaces, and suspension and transport of sediments that accumulate within the storm sewers during events. For the Riverside Beach, however, pigeons residing under the highway bridge at this location are suspected to be the source of contamination since the contamination occurs during both dry and wet weather.

A stormwater control plan was developed for the City of Belleville. Core components were (1) a source control program, (2) a centralized stormwater retrofit treatment and (3) a project by project stormwater control and treatment. Recommendations related to source control included street sweeping/catchbasin cleaning, identifying/eliminating sources of dry weather storm sewer contamination (sewer cross-connections), minimizing runoff from existing industrial and commercial properties, pet-litter control, public education and minimizing runoff volumes as a principle to be applied to new development and to road/sewer reconstruction projects.

For (2), the recommendations consist of installation of end-of-pipe stormwater treatment to treat existing outfalls, where opportunities exist. For the project-by-project stormwater control and treatment, a stormwater control policy was recommended that sets out guidelines and procedures for reviewing the design of drainage systems for all new development and redevelopment projects, as well as road and sewer improvement projects. This policy is intended to ensure that, on each project, all opportunities are utilized to reduce stormwater volumes an stormwater contamination.

Disinfection, using ultraviolet irradiation, was recommended for consideration, only for those areas of high recreational use.

Specific recommended control measures included (1) continued surveillance of the storm sewer system for bacterial sources, (2)following the recommended stormwater control policy, (3) construction of end-of-pipe stormwater quantity/quality ponds for specific outfalls, (4) implement bird control program (at the Highway 401 bridge) for reducing/eliminating the pigeon population and a public information program to discourage feeding of gulls and waterfowl. Estimated cost of the control measures was $3.18 million.

Pollution Control Plan - City of Trenton

The Trenton PCP, like that of Belleville's, was initiated to address bacterial contamination within the Trent River and the Bay of Quinte at Trenton. Phase 1 was completed in 1997. The results of the monitoring program indicated that bacterial quality (under dry weather conditions) had substantially improved since earlier studies. This improvement was due to the City of Trenton's ongoing effort to upgrade sewers and eliminate sanitary-to-storm cross-connections. Under wet weather conditions, there remains bacterial contamination of the Trent River (south of Dixon Drive Bridge to the mouth of the river). The main cause appears to be contaminated discharges from the City's storm sewers.

Phase 2 of the PCP, currently underway, is aimed at identifying the source of this wet weather bacterial pollution, and monitoring the effect of corrective actions. Corrective actions include recent elimination of cross connections in the system, proposed cleaning of sewers to flush out sediment. Wildlife, such as racoons, is also suspected of contributing to the bacteria levels in the stormwater discharges. Phase 2 will also address options with respect to phosphorus load control. Phosphorus loads from Trenton are estimated at 1,000 kg/year. Ultimately the PCP will provide a long-term strategy for stormwater pollution control from the City of Trenton.

R0025072

Severn Sound Remedial Action Plan Urban Stormwater Study

Impairments caused by stormwater in the Severn Sound AOC were problems associated with eutrophication and beach closings and effects of toxic contaminants on fish and benthic communities. Rough 1993 cost estimates for achieving a target of 20% reduction in phosphorus loadings was $35 million. The PCP was therefore initiated in 1996 to provide more definitive costs and options for managing stormwater in this AOC. The study encompassed 4 municipalities - the Town of Midland, the Town of Penetanguishene, the Township of Tay and the Township of Severn.

The PCP identified the annual pollutant loads entering into Severn Sound. A planning level model (Retrofit Stormwater Management Practices) allowed various stormwater management options to be evaluated for the entire Severn Sound area, as well as the individual municipalities. The sequence of stormwater management options takes into account source control measures firstly, followed by end-of-pipe treatment.

As a result of the PCP, loadings estimates for phosphorus to Severn Sound has been revised from 3,300 kg/year to 1,368 kg/year. A 15% reduction of phosphorus loading is achievable with best management practices. A 20% reduction of phosphorus was considered to be uneconomical. Estimated cost for the 15% reduction target was $4.3 million.

TECHNOLOGY DEVELOPMENT AND DEMONSTRATION

The total estimated cost for implementation of the PCPs for the seven cases described previously amounts over $330 million. Much of these costs are associated with the need for upgraded STPs, storage tanks for CSOs and stormwater ponds. Many municipalities need stormwater controls to be retrofitted or added to existing drainage systems in developed areas, which requires new technologies. Environment Canada GL2000 CUF, in partnership with the Ministry of Environment and municipalities, is also supporting the evaluation of technologies (described below) that have the potential to reduce the costs of implementing these PCPs.

Conventional secondary treatment plants that use activated sludge can convert to step-feed operation during wet weather to reduce bypasses and overflows. The conversion in many cases can be made with minor modifications to the process flows. In a demonstration of the procedure at the Woodward Ave. STP in Hamilton Ont., modification costing only $132,000 (1991) reduced secondary bypassing during storm flows over a ten month period by 97% (Chapman, 1998)

For CSO control, high rate treatment could provide substantial cost savings compared to sewer separation or storage and central treatment. In a 1992 study, the costs were estimated at $107 million for satellite treatment using high rate processes, $441 million using the storage and central treatment option and $3.7 to $5.9 billion for sewer separation for AOCs. The high rate treatment option is being evaluated in a pilot study initiated in 1994 (Averill et al, 1997). High rate treatment processes evaluated to date include the Storm King vortex solid separator (with and without chemicals), microscreening, parallel plate separators and tertiary filters as a polishing unit. Disinfection of CSOs treated by the effluents from the vortex separator and other unit processes was also evaluated. Key findings are (i) for the CSOs encountered, the vortex unit was able to meet the MOE's requirement of 90 mg/L TSS at a loading rate of 5 - 10 m/h, (ii) using a polymer coagulant resulted in substantially higher loadings (in excess of 40 m/h), (iii) similar loading rates could be achieved with a pilot rectangular tank, suggesting that tank geometry was not an important factor. The project has evolved into a full-scale demonstration project in which the effectiveness of the polymer coagulant is being evaluated in a CSO/stormwater tank in Toronto.

Real-time control of a sewer system is a means to take advantage of existing excess storage in a sewer system (resulting from a large sewer system, or of under utilized, or oversized sewer elements). Installation of a system of sensors, automatically operated control gates and pumps, with a computer management system can take advantage of this excess storage and reduce overflows. This may reduce control costs by up to 30%, based on European experience. A demonstration study is underway in Hamilton-Wentworth has developed the necessary software to control the extensive network of combined sewers and storage tanks (Vitasovic et al, 1993). Actual demonstration of the system is expected in 1998. The system is expected to result in improved performance in controlling overflows and reductions in capital construction of additional storage or treatment components.

Technologies using low cost measures for stormwater treatment are also under evaluation through the Stormwater Assessment Monitoring and Performance Program (SWAMP) supported by a partnership of Environment Canada GL2000 CUF the Ministry of Environment, Ontario Ministry of Transportation, Toronto and Region Conservation, and municipalities. This program is currently evaluating a number of technologies applicable to stormwater systems, including a stormwater pond performance assessment, a stormwater pond retrofit to improve water quality, underground tank performance, exfiltration and filtration systems (discussed below), flow-balancing systems (discussed below), and oil/grit separators.

In Etobicoke, an exfiltration system (constructed in 1993) is under evaluation (D'Andrea, 1998). Storm drainage is diverted to perforated pipes installed in the same trench as the conventional storm sewer. The system has great potential for reducing the costs of stormwater treatment, since it will add only 10 to 20% to the cost of sewer replacement (when road reconstruction is being carried out) and be less costly than alternate storage or treatment schemes. Since the system is built in the right-of-way, no land need be purchased, which makes the method attractive for controlling existing problems in built-up urban areas. The system performance to date has shown the system will exfiltrate up to 63 mm of rainfall. Optimization of the design is currently underway. Other aspects under evaluation include pollutant removal, groundwater transport of pollutants, and maintenance requirements.

In Scarborough, the Dunkers Flow Balancing for control of stormwater will be evaluated in 1998 (Mack-Mumford, 1998). The system uses an embayment that is sectioned off into treatment cells for removing suspended solids. Plastic suspended curtains suspended act as the cell walls. A low-cost alternative to an underground storage tank, the capital cost of the Dunkers system was $3 million versus $22 million for a storage tank.

In a separate study carried out in Scarborough, Ont., a watershed planning approach was developed to evaluate retrofit measures for existing urbanized areas (Li, 1997). In the demonstration carried out on Centennial Creek, watershed goals were translated into specific targets for reduction of total suspended solids by 50% and runoff volume by 25%. A number of different measures were then screened for applicability in the area. Retrofit measures that would fit into the municipality's capital works budget for rehabilitation and replacement of roads and sewers were included such as the exfiltration system discussed above. In addition, downspout disconnection, oil/grit interceptors, stormwater pond retrofits and new stormwater ponds to be constructed on municipal property were evaluated. A multi-efficiency model that accounted for the suspended solids reduction for both treatment measures (e.g. ponds) and infiltration measures was used to assess overall performance.

SUMMARY

Pollution prevention and control plans conducted in municipalities in AOCs have provided hard data on pollutant loadings and options to minimise these loadings from the various municipal sources (STP effluents, CSOs and stormwater). The municipalities in the AOCs now have an implementation strategy to minimize the municipal pollution to the Great Lakes. The costs of the implementation strategies are substantial. Opportunities for reducing these costs may arise from the technology evaluation projects on lower cost alternatives currently underway. Retrofit technologies that can be implemented in existing urbanized areas are important for AOCs to address existing problems. Environment Canada Great Lakes 2000 Cleanup Fund continues to provide support for these technologies.

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R0025074

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PUBLIC INVOLVEMENT STRATEGIES FOR URBAN COMMUNITIES

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ABSTRACT

Utilities contemplating projects that will affect the lives of the general public (short or long term) in many instances have a mandated requirement to also inform the public. This process, normally called public involvement, can contain any combination of these components: public information, education, and/or participation.

In many situations, utilities are not thoroughly aware of how these component parts impact their project(s) within the communities serviced. Moreover, in today's diverse yet often segregated communities it is critical to understand how communities receive, interpret and act upon messages.

This manuscript will seek to provide the strategies necessary in developing effective and successful public involvement campaigns specifically directed toward urban markets. The manuscript will address such issues as:

- Public relations v. public involvement
- Public involvement that meets the urban community's need
- Audience identification
- Partnership development for successful public involvement
- Selection of appropriate communication techniques/vehicles to deliver your message
- What to do when your community will not cooperate

The methodologies are general for application in other municipalities seeking to inform and engage their publics.

KEYWORDS

Target audiences/stakeholders/publics, CSO, public involvement, public participation, public information.

INTRODUCTION

The public involvement component of the Detroit Water & Sewerage Department's (DWSD) Long Term Combined Sewer Overflow (CSO) Control Program is a requirement set forth in the CSO provisions of the current National Pollutant Discharge Elimination System Permit (NPDES), issued by the Michigan Department of Environmental Quality (MDEQ) to DWSD.

The primary objective of the public involvement program is to inform local customers, elected officials, the press and broadcast media, and special interest groups about projects that will affect and impact their lives, and to solicit their input in the process.

The following is a partial listing of additional activities associated with projects of this nature:

- formulating a strategic approach
- creating a project identity
- reviewing and revising the media/presentation kit
- setting up an advisory coalition
- establishing a project workgroup
- researching and reviewing communication tools and public involvement activities previously conducted including surveys, wholesale customer meetings and partnership sessions.

In Detroit, the strategic public involvement plan had eight component audiences.

- Wholesale customers
- Retail customers
- Community Organizations
- Environmental Groups
- DWSD Employees
- Media
- Business leaders
- Political officials

Each audience, required a different strategy because of the information and how it should be presented. (A more detailed review of these audiences is listed separately in Audience Identification.)

The overall objectives of our communication efforts were to:

- Provide approved information to the various audiences in a timely and easily understandable and professional manner. Compile and interpret responses and make recommendations.
- Position department as an effective utility making a positive impact on issues of importance to its customers.

This paper presents methodologies and results of the City of Detroit's Combined Sewer Overflow Control Public Involvement Program.

METHODOLOGY

The very first task to accomplish in constructing a meaningful public involvement program is to gain a clear understanding of the differences between public relations and public involvement.

Briefly, the basic practice of public relations involves assuring that your publics perceive you as you wish to be perceived. While, public involvement provides a basis for shared decision-making power.

As a part of the public involvement process, a determination must be made if one or both of its component parts will be applied. The component parts are *public information and participation*. In the normal course of a public involvement program, the application of public information and participation may vary. The key is to understand when to apply each.

Public information is a one-way communication process- telling a story or providing other pertinent knowledge about the program. It is not important here that any feedback is received. Public participation on the other hand does as it name states-- involve the public's participation in the process. Participation can vary from a limited one-time occurrence to on-going. This is why the determination on the type and level of public involvement must be made at the beginning during the strategic planning stage.

To assist in constructing a public involvement program that will meet the needs of urban communities, ask and answer these questions during the planning stage:

- Why conduct public involvement?
- What are the benefits of involving the public?
- When is public involvement necessary?
- How to include the public in the process
- What level of involvement is appropriate to reach the desired outcome?
- Which public should and/or need to be involved?
- Can we define the importance of the program to the community?

R0025078

Answers could include the following:

Why Conduct Public Involvement Programs

Prioritize issues
Build credible relationships
Is required for many publicly funded projects
Public becomes part of decision making process
Expand solutions and understanding of solutions

Benefits of Involving the Public

More effective and responsive decisions
Broader acceptance and commitments
Saves time and money

When is Public Involvement Needed

The decision will affect your public unequally
The decision is a change of policy or service
The decision can't be made without public support
To build support with regulatory agencies
To build support with your customers

How to Include the Public/ Level of Involvement

One time meeting for specific closed-end decisions
On-going public involvement process
- Public meeting
- Collateral development
- One-on-one meetings
- Ad hoc advisory committee
  (Community influentials)
- Toll free information hotline

Define Importance of Program to the Community

Explain all aspects of the program
Why the program must be undertaken
Community's role
Be responsive to community concerns

Which Publics to Involve

Whose help do you need to show this is a legitimate decision and process?
Who can disrupt the process?
Who stands to gain or lose the most?
Who has the skills, contacts and experience to help the process?

In urban areas, these questions take on added importance due in part to the diversity of culture and population.

AUDIENCE IDENTIFICATION

One of the first lessons we learn in the study or communications is "Know Your Audience". This rule takes on added significance when structuring messages for urban environments. Your audience is also referred to as "stakeholders" because they have a direct and/or indirect stake in the public involvement process.

Stakeholders are comprised of internal and external publics. They may enter or have access to the process at varying stages. However, knowing who they are or represent may be the most underrated and least understood facet of the process. In urban communities, the stakeholder profile should reflect the ethnic diversity present in each city. It is therefore likely that a series of tailored messages may be needed.

Typically, stakeholder groups will consist of:

- rate payers/users
- affected residents and associates
- regulators and elected officials
- special interest groups
- internal public
-

Two specific groups-affected residents/associations and interest groups are highlighted here for discussion.

In Detroit, to effectively reach these groups, we used a strategy commonly referred to as "push-pull". We identified influentials who had credibility within the community and neighborhood groups, religious and civic associations and politics. Once identified, we sold them on our plan and enlisted their assistance in our efforts to deliver our message to the community. Community meetings were held at recreation centers, churches, schools, block club leader's homes and any other place where people would gather. As a result, we were able to communicate our message and not get side-tracked by non-related issues that residents might wish to debate.

Listed below is a profile on each stakeholder group identified for DWSD's public involvement program.

Wholesale Customers

This group has very specific concerns that could be addressed through "Wholesale Customer Meetings".

Messages that are important to this group include:
- Wastewater sites
- Alternatives
- Meter accuracy
- Water quality
- Public health issues
- The plan
- Wastewater treatment

Communication vehicles may include any of these:

1. Wholesale customer meetings
2. One-on-one & small group meeting
3. Speaker Bureau
4. Newsletter

Retail Customers (Residents/Users)

Objective

To educate the city's residential and business rate payers on the necessity for and benefits of the plan and accompanying construction.

To generate comments and input from these groups that may be of benefit to the city.

Methodology

The most efficient and cost-effective method for reaching large numbers of customers at one time would be to develop messages primarily for mass media (if the budget permits). Included here could be a mix of broadcast (primarily radio with some television) and print (community papers). If not, then community meetings are recommended. A secondary communication vehicle might include direct mail. Information of most interest to this group include benefits and/or quality of life issues.

A question and answer sheet on the project could be a good introduction to the project for retail customers. Public service announcements and a toll-free telephone hotline should also be developed and then promoted on radio and television as needed.

Other possible opportunities exist using customer service personnel. A hotline number and limited program information on a wallet sized card will allow them to answer basic questions with the public.

Possible Outcome

A) The public-at-large is provided any and all relevant information needed to be informed and educated in a timely way.
B) The utility can be positioned as proactively addressing water quality issues for all its customers.
C) A more informed public can respond one of two ways. The first and preferred response would be to accept the information with no controversy or opposition. The second and more likely response which will occur is one of some level of initial anxiety depending on how information is reported. There will be some who will be upset over cost, others will question the perception of how it will affect "their" community. This can be resolved by staying "in touch" with the community.

Community Organizations

Objective

To educate and enlist these groups to act as channels through which information can be distributed.

Methodology

Community groups like business leaders are ideal situations to use a speaker's bureau. Community organizations include churches and religious organizations, community based and civic organizations, and educational institutions.

Apart from a speaker's bureau for use at community meetings, schools, etc., these organizations can be excellent conduits to get information out to the community. Introduction of new programs, ideas and other messages can be targeted by using those in leadership positions to sell through our position.

Possible Outcomes
A) When "tapped" into properly, these groups can become additional salespeople for the project, and be available to give support at community meetings.
B) If not sought out and lobbied, some could pose serious problems because of their ability to impact community decision making.

Environment Groups

Objective

To present information in a way that addresses environmental impact concerns on the utility's plan and implementation.

Methodology

Although environmental groups will want information on rates and meter accuracy, it is believed that the issues of water quality, public health, alternatives, wastewater treatment and the long-term plan will be their "bread and butter" issues.

It will therefore be necessary to fashion information in a similar format as for the residential customers. The focus should be on the end-results; how the environment will be enhanced functionally and aesthetically.

The primary communication tools to be used in addressing this group consists of one-on-one & small group meetings, brochures and other collaterals, and a speaker bureau.

Possible Outcomes

A) If the information is received and it responds to the questions of interest/concern for these groups, a working majority buys into the utility's vision and plan, and then works with the utility by lending their support to the project.
B) Because of their size many are (small and neighborhood oriented) some of the more outspoken groups have a single issue that needs addressing. If the issue(s) can be identified and responded to, the smaller groups may not be much of a concern.
C) Use a tie-in of some sort with their issues and create a presentation for public (primarily school) use to help educate other publics.

DWSD Employees

Objective

To inform all staff with emphasis on field and customer service employees with an overview of the mechanics of the plan for the purpose of directing public inquiries to the appropriate response channels.

Methodology

Working closely with the utility's public relations division, design a "crib sheet" of basic information that employees can use if approached by the general public. This crib sheet will have in bullet format, questions and answers about the project. It will also have the toll-free hotline number that will be given for additional inquiries.

Possible Outcomes

A) Field and customer service employees will become an informal speaker's bureau as well as a distribution channel for information.
B) As a part of this methodology, a flow chart showing how information would be responded to should be created.
C) All employees will on some level become knowledgeable about the plan and its execution. As a result, employees will have some ownership in the final product.

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Media

Objectives

To provide in a controlled manner information about the plan and any related construction.

To identify and use those mediums and individuals that will be supportive voices for the project. Moreover, to identify and develop a strategy to minimize media opposition.

Methodology

The most direct method to build a support base is to be proactive in managing the media. The initial approach is to schedule editorial visits with local newspaper editors and "beat" writers. These one-on-one sessions provide for relationship building.

Additionally, reporters are always looking for information, therefore, the utility can become a conduit of information that tells the utility's story. It also opens up opportunities to position the utility in a positive way.

A media kit using current information is another tool that allows media access to information.

Important to media will be the development of a speaker's bureau and crisis/issue management plan. Both should be ready to be employed at a moment's notice.

Possible Outcomes

A) Media has to be viewed as a two-headed serpent and treated as such. The initial approach would be to enlist them as an ally, however, one should always be mindful that your interests are usually not the same. Information has to be controlled and channeled through a single voice to the media.
B) The public relations division will need to direct the majority of media contact. Therefore, the contractors' efforts should be in synergy with the utility.

Business Leaders

Objective

Educate and enlist these influentials as a support base for the project.

Methodology

The focus here will be on-on-one personal contacts with groups such as the Chamber of Commerce, civic associations and ethnic associations. These are the most probable audiences where a speaker's bureau can be used.

Possible Outcomes

A) Business leaders can use their position to pull-through our information to various audiences,
B) Employee-based education programs and information can be implemented, focusing on preventive and ecology friendly behavior of workers.

Mayor's Office and City Council

Objective

Provide timely updates and information on the progress and status of the plan.

Methodology

The department accompanied by the project administrator should provide the briefing to the city's administrator and/or their designated staff.

A strategy to inform other political officials(city and suburban) will evolve from the direction given by the administration.

Possible Outcomes

A) In Detroit, the process called for the administration to carry information to city council; DWSD personnel along with the contractor are available to answer specific questions before council.
B) Council members are approached and informed individually by a team consisting of a lead individual from the administration, DWSD and the contractor.

DEVELOPING PARTNERSHIPS

An often used formula for creating successful partnerships begin by developing trust between the participants. As discussed in audience identification, DWSD created a strategy that allowed for input and comment at different stages and with a variety of individuals. Another ingredient in establishing successful partnerships include having a firm understanding of the public involvement strategies and the desired outcomes sought.

Public Involvement Strategies

1. Clarify objectives
2. Confirm commitment
3. Understand roles, responsibilities and resources available
4. Determine the opportunities to influence the decision-making process
5.
    - Frame the problem
    - Identify stakeholders
    - Confirm the problem
    - Determine the criteria for a good solution
    - Identify potential solutions
    - Evaluate alternative solutions, identifying the trade-offs
    - Recommend decision to decision maker

5. Prepare appropriate methods and materials to meet objectives

Desired outcome

- Only involve public if they have a legitimate role
- Public Involvement comes with no guarantees
- Public is a resource to managers, not a surrogate
- Effectiveness of program, not efficiency
- Give all stakeholders opportunity to be involved
- Involving public does not equal decision up for vote
- Not everyone wants to be involved

COMMUNICATION TECHNIQUES/VEHICLES TO DELIVER MESSAGES

There are two types of people who travel. The first type are those who are not concerned with how they get from point "A" to point "B". They are normally only thinking of getting to their destination. The vehicle or mode of delivery is secondary. Then there are those who carefully plan their trip, taking into account potential detours, delays or other external factors that could affect their trip. In most situations, it is the prudent planner that enjoys the trip as much as getting to their destination. So it is also for the utility that is conducting a public involvement program. The trip itself is critical to reaching the destination or goal. In order to reduce the detours and delays, an inventory of available resources is appropriate. Vehicles that can deliver messages include:

- Billing inserts
- Logos, letterhead and mascots
- Door hangers
- Newsletters
- Fact sheets & brochures/literature drops
- Specialty items-placement, table tents
- Displays at community events
- Speakers Bureau presentations to groups
- Public events such as water week, river rescues, storm drain stenciling, tours
- Survey (telephone, mail, personal, door-to-door)
- Public meetings
- Information phone line (hotline)
- Advertisements- television, radio, print, billboards
- Media kits
- Press releases
- Television and radio interviews & talk shows
- Newspaper inserts or special sections
- CD-ROMS, Videos, Web Site, Slides

These vehicles may be used together or as a stand alone, depending on the audience. Urban residents vary in how they receive information. Choosing the correct "vehicle" to deliver the message is sometimes more important than the message when dealing with these communities.

WHAT TO DO WHEN THE COMMUNITY WILL NOT COOPERATE

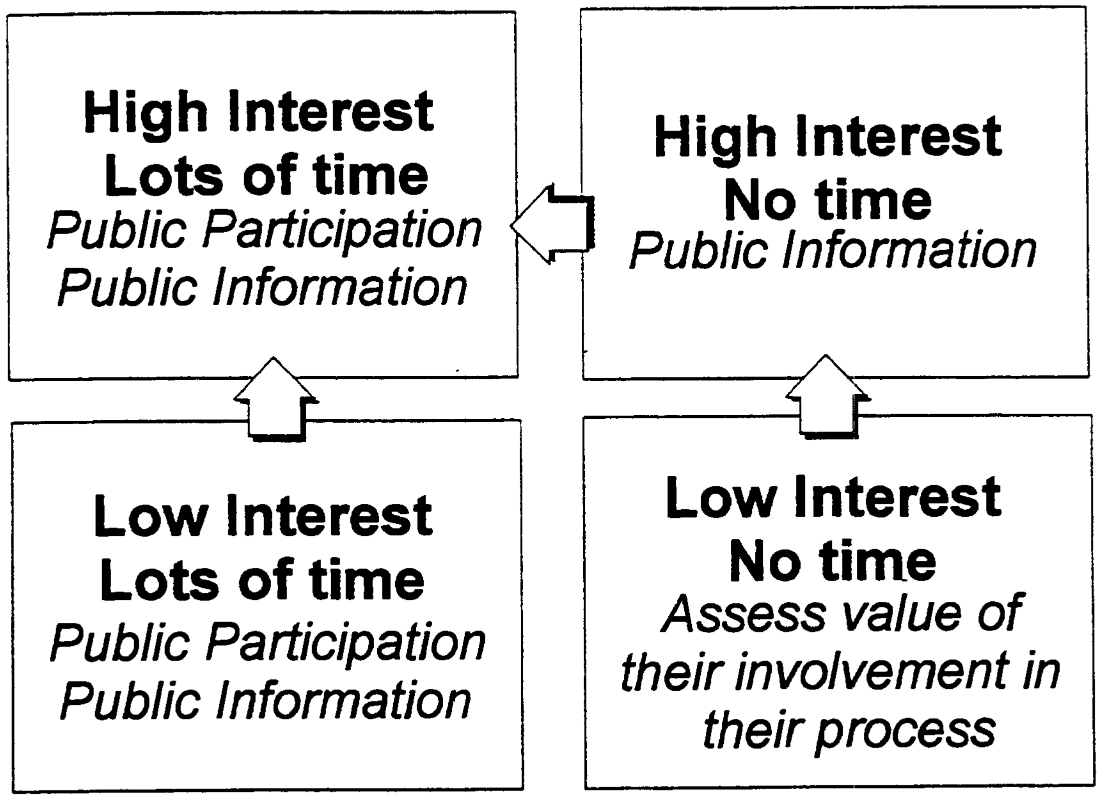
Community cooperation is the glue that holds a successful program together. Therefore, when the community will not cooperate, the original strategy should be reviewed. For example, we discussed earlier that it should be determined whether a program was information or participation driven. Knowing this could prevent lack of cooperation from the community. People may not be cooperating because they:

1) do not fully understand the process and their role or responsibility
2) may not be directly impacted or affected by the process, so it has little or no value, or
3) they simply do not wish to be involved in the process.

The following chart highlights where people should ideally be in the public involvement process.
In addition, if it can't be determined that the problem exists as described in example one or two above, leveraging the relationships established with the influentials i.e. ministers, community leaders, may be appropriate.

The public involvement process is constantly changing, people enter and exist at varying stages of the process, creating a on-going learning curve. To overcome indifference, and non-cooperation remember one very important phase "patience is a virtue and the virtuous are rewarded in the end".

Public Involvement Technique for Different Levels of Time and Interest



CONCLUSION

A successful public involvement program will follow this basic recipe:

1) Develop a strategy/plan and set up obtainable objectives
2) Identify stakeholders
3) Identify all issues that directly/indirectly impact plan; create message(s)
4) Build trust by using influentials
5) Determine level of involvement desired
6) Establish a program identity with corresponding collaterals
7) Staff with adequately trained personnel
8) Measure results throughout the process

The methodologies presented in this paper will have a wide spread and long lasting positive impact on public involvement in urban communities regardless of their size.

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Success Achieved in Reducing Sanitary Sewer Overflows Using the Program Management Approach

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ABSTRACT

After the Miami-Dade Water and Sewer Department (the Department) was hit with enforcement actions from the state and federal government to address wastewater facility capacity issues, the Director of the Department quickly realized that an organized and highly focused approach was needed to successfully comply with the requirements of the enforcement actions, to lift the County's building moratorium and to reduce the occurrence and volume of sanitary sewer overflows (SSOs). Montgomery Watson was brought on board to provide program management services for the Department on its $1 billion wastewater improvements program.

Through this program management approach, the Department has achieved a 56 percent reduction in the occurrence of wet weather SSOs over a three year period, and has seen a 66 percent reduction in the total volume of SSOs. The Department has also met more than 800 milestones set forth in the enforcement actions, many of which carry stipulated penalties of up to $10,000 per day for noncompliance. Moreover, a fast-track collection system improvement program resulted in the early removal of building moratoriums covering Miami-Dade County.

This program management approach has also provided the Department a savings in time and money, a solution to peak staffing needs, instantaneous expertise in wet weather and management issues, a uniform approach in implementing hundreds of projects and a single point of responsibility in ensuring the success of the program.

This paper will provide details on the success of the program management approach in addressing Miami-Dade's SSO challenges.

INTRODUCTION

The Miami-Dade Water and Sewer Department is the largest water and wastewater utility in the Southeast United States and serves a population of over two million located within a 600 square mile service area. The Department owns, operates and maintains over 2,400 miles of gravity sewers (up to 72-inch diameter), 640 miles of force mains (up to 102-inch diameter) and 906 pump stations. The three regional wastewater treatment plants (WWTPs) operated by the Department have recently been upgraded from a permitted capacity of 298 million gallons per day (mgd) to the current treatment capacity of 355.5 mgd.

As is common with most utilities of this size, the Department has had difficulty in controlling overflows from the sanitary sewer system, especially during wet weather events. The occurrence of these overflows drew the unwanted attention of the state and federal regulatory agencies. Over a two year period, the Department negotiated two separate Settlement Agreements with the State of Florida, and two Consent Decrees with the federal government. These enforcement actions required $1 billion in improvements to be made to Miami-Dade's wastewater facilities over a ten year period.

THE CHALLENGE

The Department was faced with some unique challenges in implementing this $1 billion improvements program. The Department had to comply with multiple enforcement actions imposed by two separate regulatory agencies that contained extremely short project completion schedules and costly penalties for not meeting the schedules. The enforcement actions also mandated a moratorium on development within the County until a large amount of the improvements had been completed. This building moratorium outraged land developers who were heretofore enjoying a fast-growing, highly profitable boom in the area of land development. The residents of the County were also outraged when their water and sewer rates more than tripled, when their streets and landscaping were torn up, and when traffic jams became the norm due to road closures. The Department was also faced with an enormous amount of work in addition to their day-to-day responsibilities, minimal staff, limited experience in addressing wet weather issues of this magnitude and a collection system that was in desperate need of repair.

PROGRAM MANAGEMENT TEAM ORGANIZATION

Confronted with these difficult issues, the Department quickly made the decision to engage Montgomery Watson to assist them in the management of this program. Montgomery Watson and its subconsultants founded the Program Management Team (PMT), which was structured to act as an extension of the Department. A 10,000 square foot office filled with a staff of 75 people was established adjacent to the Department's main office. The PMT provided the following services:

- coordination of design consultants;
- planning, design review, permitting and material procurement;
- construction management;
- developer coordination;
- multi-agency coordination;
- regulatory reporting and negotiation assistance;
- creation of a Small Contractor Development Program to increase small and minority business participation on construction projects;
- project scheduling and cost control;
- document control;
- technology transfer/training;
- and public relations/information.

THE PROGRAM

A program of improvements was established to improve the Department's management of SSOs and to satisfy the requirements of the enforcement actions. These improvements ranged from changes in operation and maintenance of the collection system to capital improvement projects, as detailed below:

- Wastewater treatment plant improvements to include an increase in treatment capacity of 67.5 mgd, the installation of odor control facilities, an optimization of plant operations.
- Construction of a regional pump station and force mains, including a subaqueous 102-inch, 5 mile force main.
- A comprehensive program was developed to monitor and inspect the 906 pump stations. The operating hours of the pump stations are monitored via elapsed time meters to determine if there are operational or capacity problems. Each pump station is also field inspected on a weekly basis, and is repaired and/or upgraded if required. To date, almost 500 pump station projects have been identified as requiring upgrade, of which, 400 pump station projects have been completed.
- A Supervisory Control and Data Acquisition (SCADA) system is being installed on all 906 pump stations to better monitor operations and identify any periodic or chronic maintenance problems.
- An aggressive Infiltration/Inflow (I/I) reduction and sewer rehabilitation program is well underway. The entire 2400 miles of collection system is being evaluated and rehabilitated as needed to minimize I/I and to improve the structural integrity of the system. Program activities include 100 percent television inspection, smoke-testing, flow metering, installation of manhole inserts, and sewer/manhole repair and replacement.
- An ordinance has been enacted which requires municipalities that discharge to the Department's wastewater facilities to implement a similar comprehensive wastewater collection system improvements program. A provision of the ordinance also requires the owners of privately-owned laterals to correct any defects.
- A grease trap ordinance was enacted to control the discharge of grease and oil from industrial and commercial users into the collection system. It was determined that the majority of pipe blockages which caused overflows, occurred due to an abundance of grease build-up.
- The development of a comprehensive sewer model and peak flow study will be utilized to refine operation and maintenance procedures to achieve optimal transmission capacity of the collection system. This model will also be used to evaluate the impact of I/I rehabilitation projects, and proposed system modifications to further address wet weather capacity issues.
- A comprehensive maintenance tracking system capable of tracking maintenance activities, equipment histories, and scheduling preventive maintenance activities has been developed. Emphasis has been placed on preventive maintenance, which has served to reduce the need for unscheduled maintenance.
- A computerized spare parts inventory management system is being utilized to ensure that a sufficient supply of routine and critical spare parts are in stock to satisfy scheduled and crisis related collection system maintenance requirements. Through this process, equipment inventories have been successfully reduced by several million dollars.

- An SSO database and contingency plan have been developed to track and minimize the quantity and volume of SSOs discharging to surface waters. The weather is monitored continually, and upon notification of an impending severe storm event, Department personnel are quickly mobilized to aid in the emergency transfer of flows away from highly sensitive areas in the collection system. In the event of a spill, investigation crews are also dispatched to correct the problem and clean the area.
- An ongoing water conservation program serves to educate the public about the importance of water conservation, and aids low-income residents through the installation of ultra low flow toilets and showerheads in their homes in order to reduce their water usage charges.

The Department has also implemented the following programs that are not required by the enforcement actions, but which serve to improve the operation and maintenance of the collection system.

- A long-term corrosion control program to include the lining of existing force mains and replacement of sewers subject to corrosion.
- The development of new design standards to minimize the potential for I/I and corrosion within the collection system.
- The installation of standby power generators at major pump stations to minimize operation interruptions.
- The development of a Geographical Information System (GIS) to aid in operating and maintaining the collection system.
- A scheduled sewer cleaning program for sewers that experience frequent grease buildup and blockages.
- An intensive cross-training program for personnel to enable them to better maintain and operate the collection system.

PRELIMINARY RESULTS

The Department has completed over 65 percent of the program improvements and is more than satisfied with the preliminary results of the program. The Department has:

- met the terms of the enforcement actions to date and has not had to pay any stipulated penalties;
- eliminated dry weather capacity SSOs and significantly reduced the quantity and volume of wet weather SSOs;
- created a more reliable, structurally sound collection system;
- improved customer service;
- appeased the developers by minimizing the duration of the building moratorium;
- grown small/minority construction businesses within Miami-Dade through the Small Contractor Development Program (59 percent of pump station projects were awarded to SCDP contractors);
- established an excellent relationship with the regulatory agencies, who now acknowledge that Miami-Dade has a model program; and,

- has successfully educated the public on the value of the program improvements and related issues through different media presented in English, Spanish and Creole.

CONCLUSION

Through this program management approach, the Department continues to be successful in reducing its SSOs and in meeting the requirements of the enforcement actions. Moreover, this approach has allowed the Department to maintain its focus on providing good customer service throughout the implementation of this massive improvements program.

CALCULATING INFLOW IN COMPLEX HYDRAULIC NETWORKS WITH PUMPED FLOW INPUTS AND BYPASSES

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ABSTRACT

When performing flow metering for evaluation of infiltration/inflow levels in a sanitary sewer system, meter locations should be selected to avoid manipulation of data between upstream and downstream meter sites to obtain net flows within a defined area. Sites also should be selected to avoid the impact of force main discharges upstream of the meter because analysis of the inflow components from pumped flow data is more difficult. This paper will examine a large scale metering project in Gwinnett County, Georgia. The county is served by multiple wastewater reclamation facilities, which receive flow from approximately 130 pumping stations. Various pump stations and treatment facilities have bypass structures, which send excess flow beyond the capacity of the facility to an alternative downstream facility. This introduced additional difficulty into an analysis effort that was daunting by its sheer size alone.

KEY WORDS

Flow metering, bypasses, inflow, data analysis

INTRODUCTION

A unique aspect of this wastewater system is that the collection lines and customers are often located away from the treatment facilities best equipped to handle the flow. The county Department of Public Utilities has employed a strategy of pumping flow from the sewersheds with limited treatment capacity to those within the county with available capacity. Some of the newer pumping stations have been designed to allow flow to by-pass to older treatment facilities, while "shaving off" peak flows to newer facilities in alternate sewersheds. The combination of multiple pumped flow inputs and four major by-pass points provided challenges when choosing meter sites and analyzing data. These features of the Gwinnett County system are illustrated on figure 1.

The metering project for Gwinnett County was designed to provide countywide data for the winter 1997 monitoring season. Data from 101 temporary sites was collected. Select meter sites were subject to the effects of pumped flow inputs because the large number of sites, pumping stations, and network layout prevented this condition from being avoided in every case. Four locations were monitored to track by-pass flows. Although it is always preferable to analyze flow meter data which is independent from other locations, this is rarely feasible. In particular, the calculation of peak flows to obtain inflow quantification is complicated at these sites. Pumping stations act to dampen peak flow effects, which are otherwise clearly observed in a gravity flow scenario.

METHODOLOGY

A variety of challenges exist when conducting analysis of flow data from meter locations subject to upstream pumped flow and by-passes.. These include:

- The shape of the pumped flow hydrograph is not the same as that of a gravity flow sewer hydrograph.

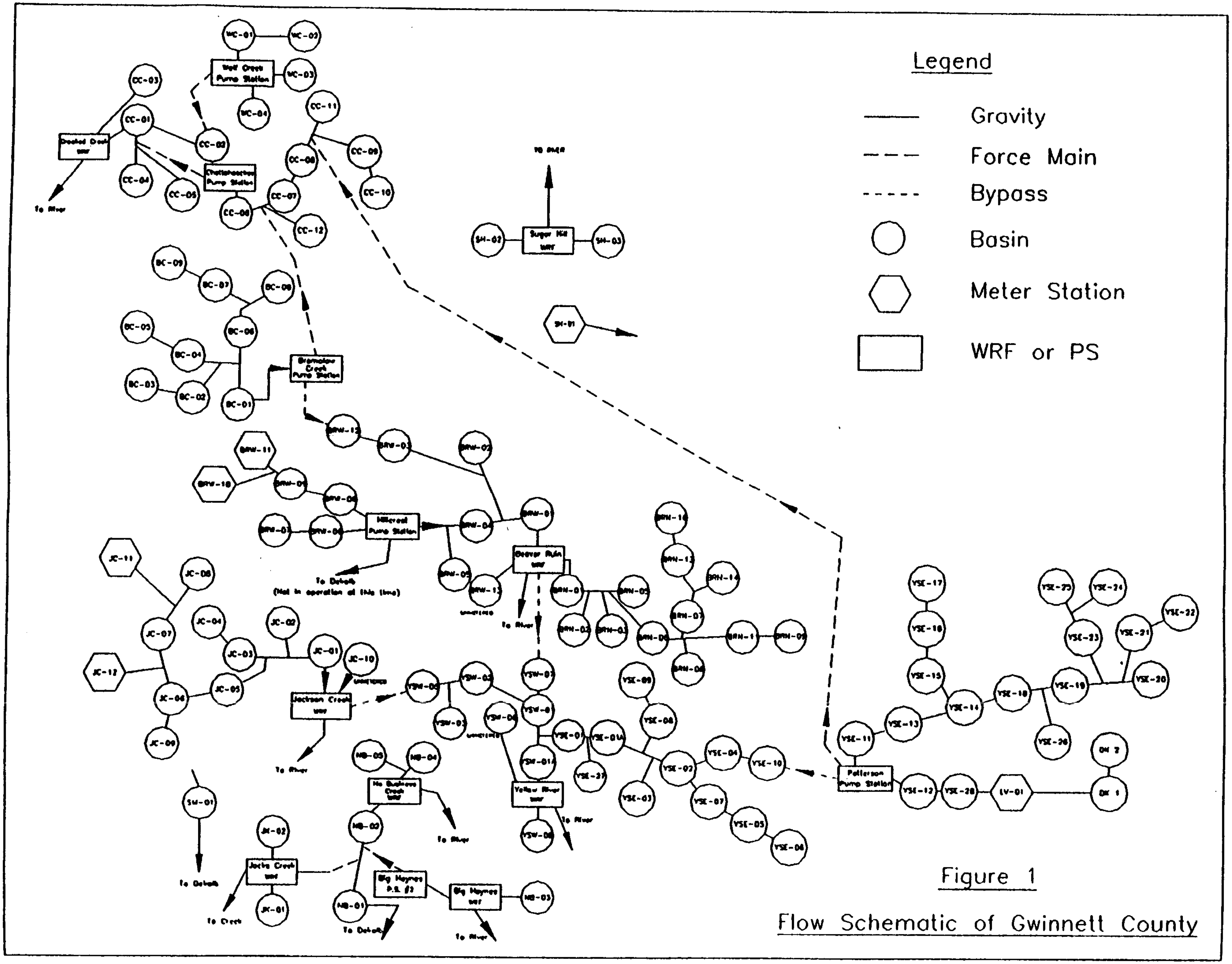

Figure 1

Flow Schematic of Gwinnett County

- The point in time of peak flow from an upstream site is extended because of wet-well detention times.
- By-passed flows are not predictable and may vary without respect to inflow related events.

Inflow in a sanitary sewer system is defined as extraneous flow that is a direct result of stormwater runoff. Inflow may enter the sewer from a variety of sources including; downspouts, area drains, storm sewer cross connections, and manhole covers. Inflow replaces valuable system capacity in collection networks and treatment plants and may cause sanitary sewer overflows (SSO) if present in sufficient quantities. The determination of inflow rate is made by comparing the antecedent, dry-day conditions at a given meter site with peak flow recorded at the meter site during a rainfall event. The rainfall during the peak 60-minute rainfall intensity was plotted against peak inflow for a variety of storms to determine the relationship between the data sets. For example, if the wet-day flow rate at the peak period is 4,690 liter/minute (L/m), or 1.75 million gallons/day (mgd), and the corresponding dry-day flow at the corresponding time is 3,943 L/m (1.50 mgd), the inflow is expressed as the wet-day flow rate minus the dry-day flow or 657 L/m (0.25 mgd).

Several techniques were applied to facilitate inflow analysis in light of the limiting factors mentioned above. These included:

- Averaging data over known pumping cycles.
- Differential time adjustment to match peak flows between upstream and downstream locations, and
- Graphical hydrograph comparison for data verification and cumulative effect analysis.

Data Averaging

Data may need to be averaged over the normal pumping cycle when picking a point to analyze for inflow in the case of a pumping station with constant speed pumps. The hydrograph produced by pumped flow does not mirror the actual flow in the system upstream of the pump station. The observed peak is limited by the maximum capacity of the pump not the actual flow that would otherwise be observed. (In many cases, the pump capacity will exceed the peak inflow rate tributary to the station.) What will occur is that the frequency of pumping increases during wet-weather. The minimum (pump off) and maximum (pump on) rates will not vary, but the peaks will be closer together with respect to time. Therefore, the data must be averaged over a period of time during the storm event. It is not practical to select a discreet data point.

Differential Time Adjustment

The analyst should account for the time difference between peaks observed at connecting meters, based on the distance between sites, and whether or not they are connected by gravity sewer or force main. For situations where pumped flow inputs occur, the length of sewer and the flow velocity can be determined to estimate travel time. This travel time can be significant if the pumped flow originates from a long distance away. The travel time is subtracted from the time the peak is observed at the downstream meter. The peak comparison can then be made for the same storm event at equivalent times.

Graphical Comparison

An effective means to analyze interrelated sets of data is by graphical superimposition to detect observable time of concentration differences in upstream flow inputs, including pumped flow and by-passed flow. This technique allows for analysis of storm inflow effects at the desired meter location while accounting for the influence of the upstream inputs. The downstream hydrograph can be viewed as a composite of the upstream hydrographs. In this way, choosing the peak inflow point for the analyzed meter site was done after accounting for the upstream peaks finally flowing past the meter site. This technique is used in conjunction with differential time adjustment to pick the time of peak inflow. Once the true peak point is established, then the upstream inflow values are subtracted from the desired downstream meter location. The difference is the amount of inflow attributable to the drainage area in question, and not upstream sources.

RESULTS

Data Averaging

Initially, data was collected regarding pumping stations to determine whether or not they were supplied with constant speed or variable speed pumps. This information assists the analyst when interpreting the flow data. An example of a meter site subject to upstream pump station influence is illustrated in figure 2. The upstream pump station serves a residential area and is supplied with constant speed pumps. The graph represents flow data averaged over 5-minute intervals. Longer pump run times produce higher flow rates at expected times such as mid-moming and early evening. The general shape of the graph depicts a typical diumal hydrograph; however, the effects of pumping are also apparent from the continuous oscillation of flow throughout the day. This makes picking the true flow peak difficult. In this case, the data was graphed using 15-minute averages. This produced a smoother graph with an obvious peak at 11:25 p.m., as shown in figure 3. The preceding dry-day flows are superimposed to show the expected flow rates during dry conditions. The dry-day peak flow for comparison was determined to be at 11:35 p.m. after examination of tabular 5-minute data. This point accounts for pumping. This example produced a wet-day flow of 2847 L/m (1.083 mgd) and a dry-day flow of 1698 L/m (0.646 mgd). The net difference is 1149 L/m (0.437 mgd), which is the inflow for this location.

Differential Time Adjustment

The peak hourly intensity for the rainfall event in the above example began at 10:15 p.m. After allowing for detention time in the wetwell, a clear peak can be observed in figure 3. This peak is not shifted radically, occurring about one hour after the peak rainfall intensity. It is important for the analyst to understand the nature of the collection system upstream of the meter site. In this case, the pumping station has approximately 1,400 linear feet of force main which discharges about 6,000 linear feet upstream of the meter location. It is known that the gravity sewer velocities in this portion of the system range from 0.61m/s (2 ft/s) to 1.22 m/s (4 ft/s). this would produce a time of concentration of 40 to 80 minutes. The peak was observed at 11:25 p.m. and is consistent with the known collection system criteria.

Graphical Comparison

Figure 4 illustrates how superimposition on a common scale of wet-day/dry-day and upstream/downstream meter data helps the analyst to interpret inflow effects. The feature that is initially obvious is the shift of inflow peaks from the upstream, by-pass meter at site BRW-12 to the downstream meter at BRW-03. The BRW-12 site measures flow by-passed from an upstream pump station at Bromolow Creek. This effect is consistent with the known conditions of the system and serves as a verification check of the data from both locations.

It is also observed that anomalies in flow can occur from by-pass sites. These types of sites can have broad variations based on either the mode of operation of the pumping station or treatment plant just upstream. In this case, BRW-12 shows a dry-day flow spike at roughly 6:30 p.m. This would skew the inflow results downward if this point was chosen as a dry-day reference. It was helpful to use these points, however, to determine the differential time adjustment between sites.

For this example, rain effects are very noticeable at each site. Dry-day and wet-day flows track closely until the peak storm intensity occurs at 2:15 p.m. Both curves then begin a pronounced increase. The peak is observed at BRW-12 at approximately 4:15 p.m., reflecting the relatively large drainage area to this meter. The peak at BRW-03 is shifted to approximately 5:15 p.m., reflecting the separation between sites. The calculated gross inflow at site BRW-12 is 1,632 L/m (0.621 mgd) and 4,101 L/m (1.560 mgd)

Figure 2
FLOW vs TIME
YSW-25

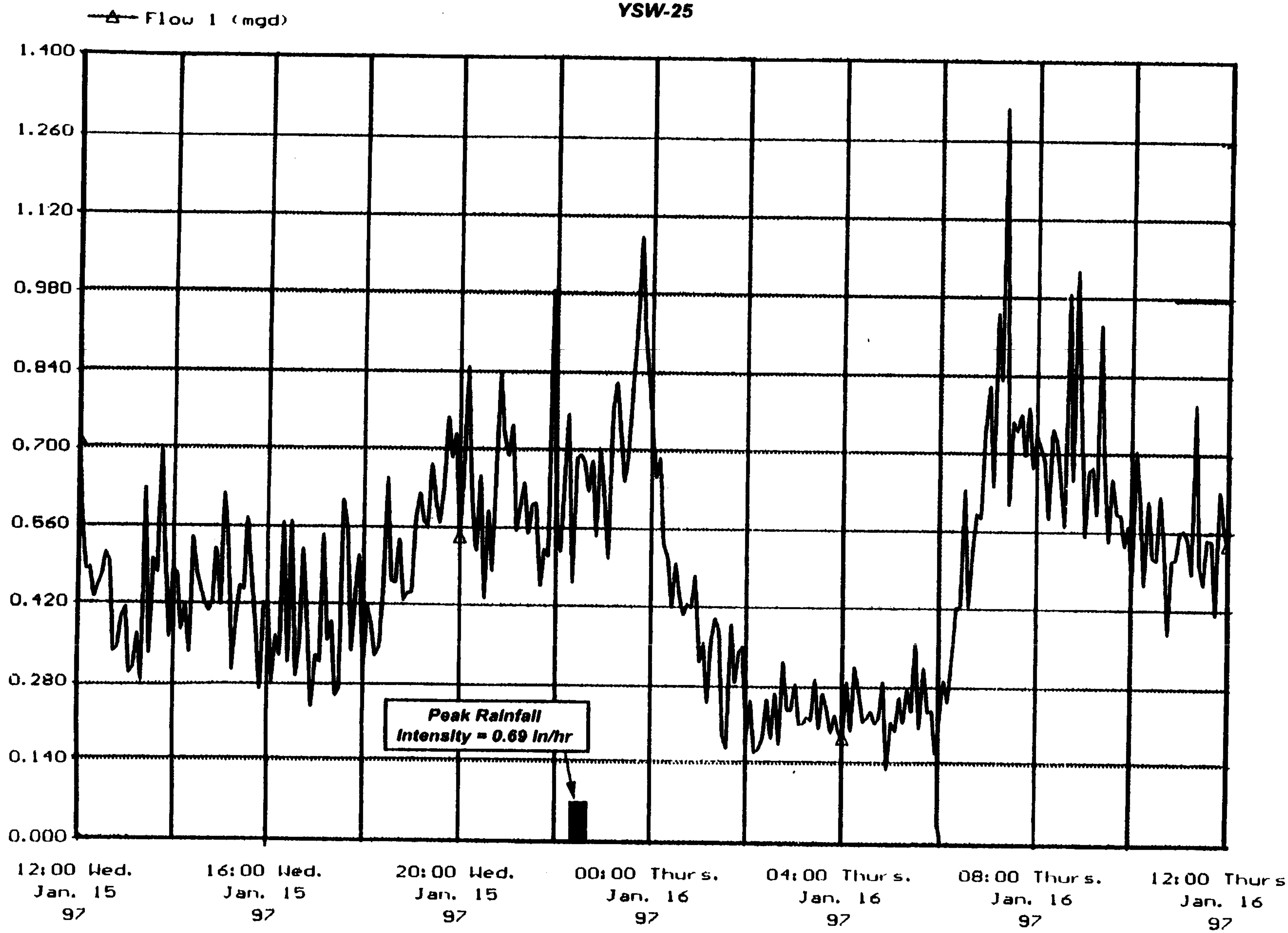

Figure 3
FLOW vs TIME (day)
YSW-25

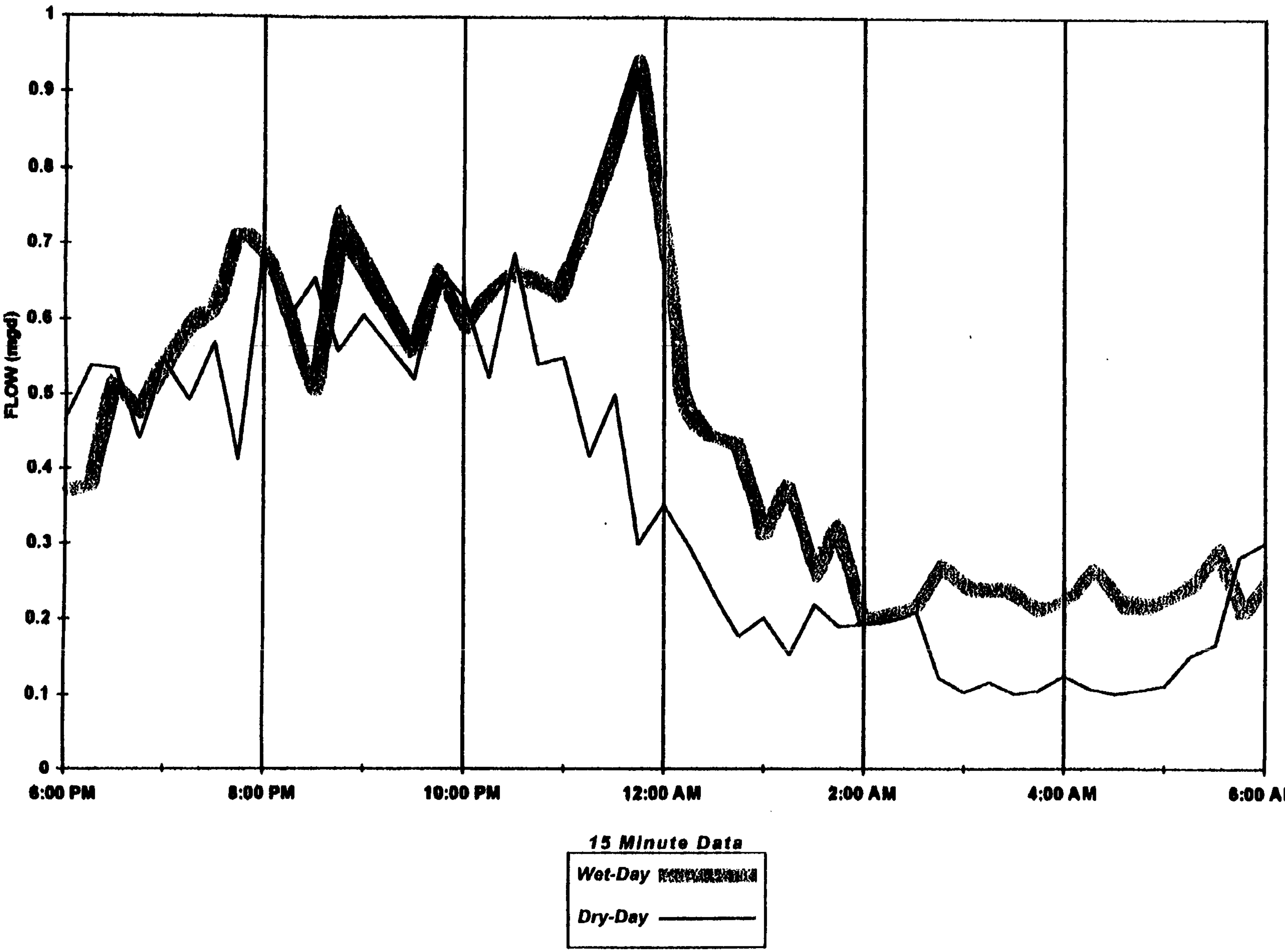

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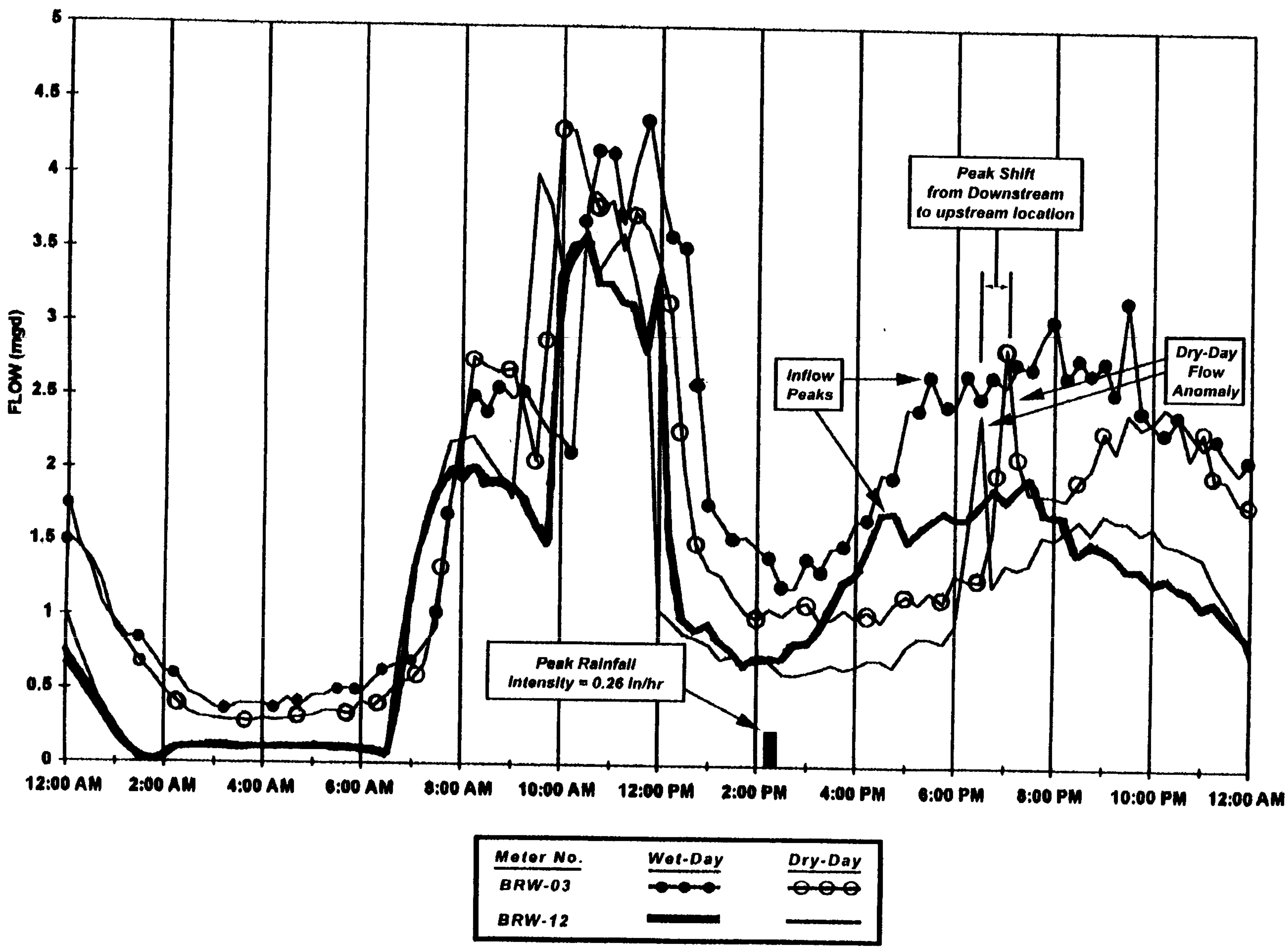
Figure 4
FLOW vs TIME (day)
BRW-12 and BRW-03



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at site BRW-03. The net flow from BRW-03 is 2,469 L/m (0.939 mgd). Table 1 shows the data values extracted from the graphs for inflow analysis.

Table 1. **Inflow Computation Example Data**

	Peak Wet-day Flow (A)			Peak Dry-day Flow (B)			(A)-(B)
Meter Location	Rate (L/m)	Date	Time	Rate (L/m)	Date	Time	Inflow (L/m)
BRW-03	7,313	2/21/97	17:35	3,212	2/20/97	17:05	4,101
BRW-12	3,912	2/21/97	17:35	2,279	2/20/97	17:05	1,632
				Net Inflow at BRW-03			2,469

DISCUSSION

If data for a meter site which is subject to pumped flow inputs is not averaged, it is possible to pick a data point on the downside of a pump cycle, giving an inaccurate result. With respect to differential time adjustment, it should be noted that small pump stations or overdesigned stations may have a large impact on inflow analysis because of relatively long wet well detention times. It is important that the analyst understands the exact nature of upstream pump stations to assess probable detention times. Typical inflow analysis requires a minimum of three to four measurable storms to generate an inflow to rainfall intensity relationship. When plotted on log-log paper, the points will form a line from which a linear regression analysis can be performed. The level of confidence of data correlation is improved with additional data points. When dealing with the effects of pumped or by-passed flows, it is desirable to obtain additional data points to improve the fit of the inflow-rainfall intensity curve. This helps mitigate the potential error introduced when interpreting pumped flow data.

CONCLUSIONS

Although meter sites may be chosen to avoid pumped flow or other irregular inputs, they cannot be avoided in all cases. The techniques described in this paper provide approaches which the data analyst may employ to account for the unique flow patterns produced by pumped flow and by-passed flow inputs.

AN INTENSIVE FIELD SAMPLING PROGRAM IN SUPPORT OF A NUMERICAL TOXICANT FATE AND TRANSPORT MODEL AND RISK ASSESSMENT OF THE DUWAMISH RIVER AND ELLIOTT BAY, WASHINGTON

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ABSTRACT

The Duwamish River and Elliott Bay urban estuary, located in Seattle, Washington, is an important natural and economic resource for the Puget Sound region. A field sampling program was undertaken in the winter of 1996-97 to provide data to support a toxicant fate and transport modeling effort and risk assessments on combined sewer overflow (CSO) discharges in the Duwamish River and Elliott Bay system. Results of this CSO Water Quality Assessment will provide decision makers with information integral to long-range CSO control planning.

The field program sampled conventional parameters, bacteria, trace metals and organic compounds in matrices including the water column, sediments, CSO discharges and fish and invertebrate tissues. Water column and sediment samples were collected weekly, with daily water samples collected for the three days following CSO events. CSO samples were collected by automated samplers. Biological samples were obtained through a number of methods, including fishing and trawling. A special study with transplanted and wild mussels documented differences in tissue chemical concentrations encountered in dry and wet seasons. Surveys were undertaken to characterize differences in the benthic community proximal and distal to a CSO.

A number of specialized sampling and analytical techniques were used . Organic concentrations were too low to detect using our traditional sampling and laboratory methods. Semi-permeable membrane devices were deployed to assess water column concentrations of organic compounds, these samplers estimate the average concentration of organic compounds over time. Low level mercury sampling was also employed to estimate mercury concentrations in the water column.

KEYWORDS

water quality, combined sewer overflows, field sampling program, Duwamish Estuary

INTRODUCTION

The King County CSO Water Quality Assessment for the Duwamish River and Elliott Bay was funded in 1995. Its purpose is to provide information for making decisions about the future of the CSO control program in King County. The State of Washington has adopted a long-range standard for CSO control equivalent to no more than one overflow per discharge point per year in an average rainfall year. The long-range planning process for wastewater treatment in King County has estimated the cost of achieving this standard to be $600,000,000.

The primary question, on the part of county decision makers, is: What is the significance of risks caused by CSOs and how can the region most effectively address these risks? Evaluating these risks will provide decision makers with information for optimizing the CSO program through prioritization of current and future CSO control projects.

The Water Quality Assessment was designed to answer these questions using both the US EPA Ecological Risk Assessment Framework (EPA, 1996) and the Water Environment Research Foundation (WERF) protocols for Ecological Risk Assessment (WERF, 1996). Risks to people are being assessed within the framework of ecological risk but using the EPA Human Health Risk Assessment Guidelines (EPA, 1989). The first objective of the Water Quality Assessment was to understand the existing conditions of the Duwamish River and Elliott Bay in terms of level of risk to aquatic life, wildlife, and people who use these water bodies. A second objective was to understand the significance of CSO stressors compared to those of other sources.

The purpose of the field sampling program for the Water Quality Assessment was to provide empirical data that could be used in the human health and ecological risk assessments and to calibrate the toxicant fate and transport model. The field sampling program was integral to addressing the first objective of the Water Quality Assessment - the risks to human health, aquatic life, and wildlife from existing conditions in the Duwamish River and Elliott Bay.

COMBINED SEWER OVERFLOWS

Combined sewer overflows or CSOs, are discharges of untreated sewage and stormwater released directly into surface waters during periods of heavy rainfall (King County 1995). Combined sewers, those which carry sanitary sewage and storm runoff in a single pipe, are found in much of metropolitan Seattle. Because combining systems was the standard engineering practice, all of Seattle's sewers built from 1892 until the early 1940s were combined sewers. As newer sewers were installed in Seattle, storm water was separated from household, commercial, and industrial wastewaters.

Combined sewer overflows serve as safety valves for the sewage treatment system. In combined systems, the trunk sewers and interceptors have fixed capacities. During periods of heavy rainfall, wastewater volumes may exceed the capacity of the sewer pipes to convey the wastewater to the treatment plant. To prevent damage to the system and to prevent sewers from backing up into homes, combined sewers are designed to overflow. Typically, overflows are designed to discharge to rivers and marine waters where the flushing action of tides and currents can disperse pollutants.

City of Seattle and King County (formerly Metro) overflows occur within the study area in both the Duwamish River and Elliott Bay. From 1981 to 1983, nearly 2.4 billion gallons of untreated sewage were discharged from this system each year. As a result of control efforts, this volume was reduced to 1.8 billion gallons per year by 1994 (King County 1995).

PROJECT METHODOLOGIES

The methodologies for ecological and human health risk assessment designed by the US Environmental Protection Agency (USEPA 1989; 1992; 1994; 1996; and the Water Environmental Research Foundation (Parkhurst et al. 1996) are being used to describe risk that may be occurring to aquatic life, wildlife, and people who use the Duwamish River and Elliott Bay, and how the risk could change with control of CSOs.

A model that predicts the concentrations of chemical stressors and other potential changes in the water body will drive the risk assessment. The model is essential to predict conditions in the estuary if CSOs are eliminated. The model also provides a way to fill gaps in data on current conditions. The modeling effort is supported by a sampling program that allows model calibration and detailed characterization of the physical, chemical, and biological stressors entering the Duwamish River/Elliott Bay ecosystem. This paper will describe the various components of the field sampling program which provided the input to the water quality model and risk assessment.

STUDY AREA DESCRIPTION

The Water Quality Assessment study area, shown in Figure 1, includes the Green-Duwamish River from just upriver of the East Division Reclamation Plant (Renton Sewage Treatment Plant) downstream to where it enters Elliott Bay, a distance of approximately 24 kilometers (km). The study area also includes the portion of Elliott Bay east of an imaginary line drawn from Duwamish Head north to Magnolia Bluff.

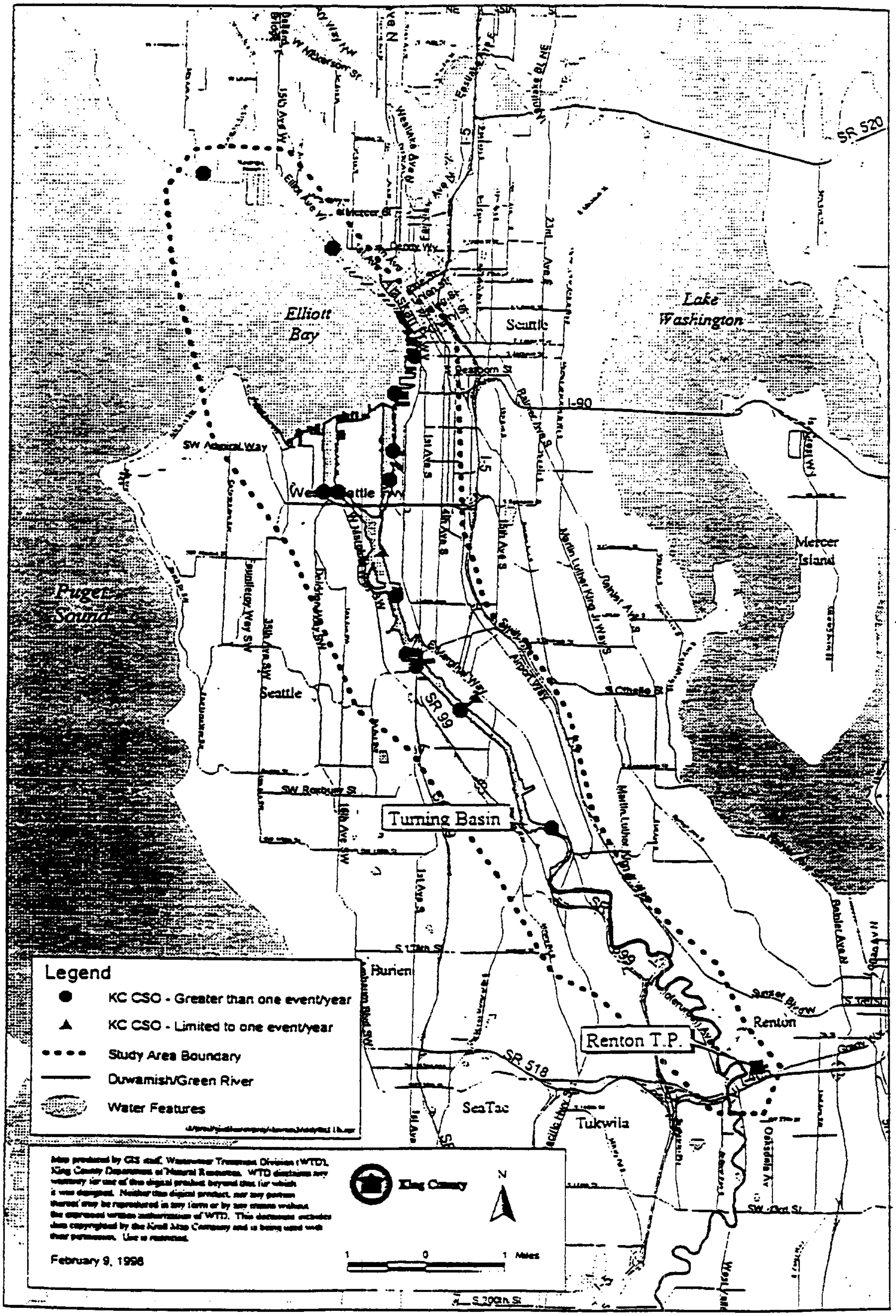

Figure 1. Water Quality Assessment Study Area

The lower Duwamish River is a highly industrialized, salt-wedge estuary influenced both by river flow and tidal effects. At its mouth, the river splits into the East and West Waterways, flowing around Harbor Island into Elliott Bay. The river is considered an estuarine system, exhibiting both marine and fresh water characteristics. During periods of normal river flow, the salt wedge extends upriver approximately 13 km with its terminus or "toe" near the navigational turning basin. From the turning basin upriver to the Renton Sewage Treatment Plant, the river flows through areas of light commercial and residential uses.

The lower portion of the Duwamish River, below the turning basin, has been straightened, dredged, and rip-rapped to facilitate navigation and commerce. Upriver of the turning basin the river continues to flow through its historic channel. River depths range from approximately 17 meters (m) near the mouth to less than a meter in some areas of the upper portion of the study area. Bottom sediments range from coarse sand to fine silt depending on sediment sources and river hydrodynamics. River flows are largely controlled by releases from the Howard Hansen dam, located in the upper Green River watershed. Summer flows, gaged at Auburn, Washington are in the range of 7 cubic meters per second (cms). Winter flows average approximately 45 to 55 cms with peak flows greater than 150 cms during storm events.

Elliott Bay, approximately 21 square km in area, forms the western boundary of the commercial core of Seattle. Land use surrounding the bay is mainly marine-oriented industrial and commercial with marine traffic on the bay heavy at all times of the year. The bay opens to the main basin of Puget Sound to the east.

Depths in the bay on the western edge of the study area range from 150 to 180 m while depths near the Seattle waterfront are in the range of 10 to 20 m. The open portion of Elliott Bay is dominated by Puget Sound marine water masses with the fresh water lens from the Duwamish River occupying the upper 5 m. Natural shorelines with intertidal zones are present along the northeast and southwest shores of the bay. In the commercially developed portions of the bay, piers and rip-rapping have replaced natural shorelines. Bottom sediments in the bay range from fine sediment to coarse gravels and cobble.

FIELD SAMPLING PROGRAM FOR THE WATER QUALITY MODEL

The field sampling program for the water quality model generated data from three matrices; CSO effluent, receiving water, and sediment. These data will be used to model the chemical, physical, and microbiological characteristics of the Duwamish River and Elliott Bay during both storm and non-storm conditions. All sampling and routine analytical work was performed by staff of the King County Environmental Laboratory.

CSO Effluent

Effluent samples were collected during discharges from five CSO locations. At two of the locations, sequential and composite autosamplers were placed side-by-side at the outfall structure. The placement allowed comparison of effluent chemical and microbial concentrations at various times during the discharge event (sequential sampling) to concentrations over the entire duration of the event (composite sampling.

At the third location, three composite autosamplers were placed with the sampling intakes at three different depths in the effluent stream. This placement allowed comparisons of concentrations at the bottom, middle, and surface of the effluent stream.

Placements at the fourth and fifth locations included, respectively, side-by-side sequential autosamplers to provide replicate sampling for field quality control and a single, composite autosampler.

Intake lines for the autosamplers were placed in the wet well at each location. Sampling events were triggered by flow conditions monitored by King County's computerized flow-monitoring system SCADA (Supervisory Control And Data Acquisition).

CSO effluent was routinely analyzed for the following conventional parameters: chemical oxygen demand, total organic carbon, volatile suspended solids, ammonia nitrogen, nitrate/nitrite nitrogen, and total suspended solids. Chemical oxygen demand, total organic carbon and volatile suspended solids provided an estimate of the organic content of the CSO effluent. Analysis of the various forms of nitrogen allowed evaluation of the contribution of these nutrients to receiving water from CSO effluent. Conventional parameters measured in the field included temperature, conductivity, and pH.

Metal parameters included the following thirteen priority pollutant metals: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Analysis of these samples was performed by ICP-MS (inductively coupled plasma mass spectroscopy) to obtain the lowest-possible detection limits. The samples also were analyzed by ICP (inductively coupled plasma optical emission spectroscopy) for calcium and magnesium to allow a hardness calculation since fresh water quality criteria for metals are hardness normalized.

To obtain the lowest possible detection limits for mercury, a separate low level mercury study was also undertaken for CSO effluent and receiving water. Sampling methodologies followed guidelines specified in EPA Method 1669, the "clean hands/dirty hands" technique. Collection of a greater number of field QC samples allowed evaluation of the final quality of the data. Low level mercury analysis by Cold Vapor Atomic Fluorescence was performed by Brooks Rand, Inc. of Seattle, Washington.

Organic parameters included all of the priority pollutant base/neutral/acid (BNA) extractable semivolatile organic compounds with the addition of caffeine and coprostanol, two compounds which act as tracers for the sewage component of CSO effluent.

Fecal coliforms were routinely analyzed in CSO effluent samples as an indicator species for other pathogens.

Receiving Water

Receiving water samples were collected from 21 stations in the Duwamish River and Elliott Bay to evaluate the chemical, physical, and microbiological characteristics of receiving water during both storm and non-storm conditions. Samples were collected over two 26-week periods.

At most stations in the river and bay, samples were collected from two depths; one meter below the surface and one meter above the bottom (or a maximum depth of 20 m at the deeper stations). Sampling at two depths allowed an evaluation of the differences between the overlying fresh water and the salt water at each station. At very shallow stations samples were collected only at a depth of one meter. Samples were collected weekly except in the event of storm conditions causing a significant discharge at two or more of the target CSOs. During storm conditions, samples were collected at all 21 locations daily for a period of three days following the CSO discharge event.

Routine receiving water samples were collected either from the King County Environmental Laboratory's research vessel *Liberty* or from shore. In non-navigable areas, receiving water samples were collected from bridges. Samples collected from bridges employed Van Dorn or Niskin bottles lowered by rope to the water surface. Sample bottles were lowered to a depth of approximately one meter below the surface and the closing mechanism tripped to facilitate the collection of a discrete sample.

Samples collected from the *Liberty* used Niskin bottles deployed on a hydrowire. The Niskin bottles were lowered on the hydrowire to depths of one meter below the surface and one meter above the bottom (or 20 meters in depth) simultaneously at each station.

Receiving water was routinely analyzed for the following conventional parameters: total organic carbon, volatile suspended solids, ammonia nitrogen, nitrate/nitrite nitrogen, and total suspended solids. Where the receiving water is fresh, analysis of chemical oxygen demand was also performed. Conventional parameters measured in the field included dissolved oxygen, temperature, conductivity/salinity, and pH.

Fresh and marine receiving water was analyzed for the same suite of metals mentioned above by ICP and ICP-MS. The salinity and dissolved solids concentration of marine water, however, imparted a high degree of interference to the ICP-MS analysis. Special sample preparation was conducted on marine receiving water samples prior to analysis. The sample preparation consisted of a "reductive co-precipitation" process which both removed chloride and other dissolved solids interferences as well as concentrating the sample to improve detection limits.

BNA compounds (including caffeine and coprostanol) were analyzed for every fourth set of receiving water samples. Grab sampling did not prove to be the most successful method for detecting organic constituents and routine analysis was done to confirm that these compounds were not present above standard detection limits.

Receiving water samples were routinely analyzed for fecal coliforms.

In addition to the receiving water sampling scheme described above, separate sampling tasks were undertaken for the evaluation of trace-level organics and mercury.

To obtain the lowest possible detection limits, special sampling events for the collection of mercury samples were undertaken in association with Brooks Rand, Inc. of Seattle, Washington. Sampling from the *Liberty* employed a peristaltic pump and Teflon® tubing to allow virtually hands-free collection of water samples *in situ*. This minimized contamination either from sampling equipment or the environment. Sampling from shore employed a Teflon® bailer and associated deployment equipment. Special precautions outlined in EPA Method 1669 were followed and several field QC samples were collected, including tubing blanks, atmosphere blanks, filter blanks, and bailer blanks. Sampling equipment was supplied and Cold Vapor Atomic Fluorescence analysis of mercury was performed by Brooks Rand.

Organic compounds are difficult to detect in ambient receiving water samples collected as discrete grabs. To better understand the existing organic compound concentrations in receiving water, semipermeable membrane devices (SPMD) were employed to collect time-integrated water samples. The SPMD were, essentially, pre-cleaned polyethylene sheets which accumulated organic compounds over time. The SPMD concentrate non-polar or lipophilic compounds over a specified time period. Resulting data can then be used to estimate the average receiving water concentrations by applying compound-specific partitioning coefficients. SPMD analysis was performed by Battelle Marine Sciences Laboratory in Sequim, Washington. Analytical parameters included polynuclear aromatic hydrocarbon (PAH) compounds, chlorinated pesticides, polychlorinated biphenyl (PCB) Aroclors®, and PCB congeners. The SPMD were deployed at two locations in the Duwamish River for a period of two weeks. SPMD were attached to a rope-float-anchor assembly which was deployed and retrieved as quickly as possible to minimize contamination. To assess possible contamination by airborne organic compounds, a trip blank was exposed to the air for the same amount of time as one SPMD during deployment and retrieval.

Sediment

Sediment samples were collected from five locations in the Duwamish River for a period of 18 weeks. At one CSO location, sediments were collected weekly for the entire 18 weeks. At a second CSO location and at an in-river reference location, sediments were collected weekly for a period of 14 weeks. At two other in-river reference locations, sediments were collected weekly for a period of four weeks. At each location, a single sample was composited from 10 sediment grabs, laid out on a 5-m square grid. Samples were collected from the top two centimeters (cm) at each grab station. Sediment samples were collected from the *Liberty* using a modified, stainless steel Van Veen grab sampler. The grab sampler was lowered on a hydrowire and, upon retrieval, the sample was visually inspected for acceptability. If acceptable, a 200 cubic centimeter aliquot was collected from the sample using a stainless steel cookie cutter and placed in a stainless steel bowl. An aliquot was collected from each of the subsequent nine grab stations and the sample thoroughly homogenized before placement in sample containers. Oxidation-reduction potential, was measured in each of the ten individual grab samples with an electronic meter.

Sediment was routinely analyzed for particle size distribution, total solids, total organic carbon, ammonia nitrogen, and total sulfides. Particle size distribution and total sulfide analysis was performed by AmTest, Inc. of Redmond, Washington. Analysis of total solids allowed sediment organic and metal data to be normalized to dry weight. Some organic data are also normzalized to organic carbon, based on the results of the total organic carbon analysis.

Sediment analysis also included those metals regulated under the State of Washington Sediment Management Standards (Chapter 173-204 WAC) which include arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc as well as the remaining priority pollutant metals (antimony, beryllium, nickel, selenium, and thallium). The mineral metals, aluminum and iron, also were analyzed to provide a potential method for normalizing other metal concentrations to local geological conditions. Organic forms of metals, including butyltin isomers and methyl mercury, were also analyzed in sediment due to their potential toxicity through bioaccumulation. Methyl mercury analysis was performed by Frontier Geosciences, Inc. of Seattle, Washington.

Sediment samples were analyzed for all organic parameters specified in the Sediment Management Standards. These parameters include the BNA compounds and PCBs.

FIELD SAMPLING PROGRAM FOR THE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

The field sampling program for the ecological and human health risk assessments generated two types of data; chemical concentrations present in fish and shellfish tissue and abundance of benthic infaunal organisms. These data will be used directly in calculations used to ascribe risk to human health and the ecological receptors established as risk assessment endpoints for the WQA project.

Bioaccumulation of Chemicals in Fish and Shellfish

Chemical concentrations present in fish and shellfish from the Duwamish River and Elliot Bay were evaluated through two studies.

An *in situ* bioassay using transplanted mussels was conducted twice near several CSO outfalls and in-river reference stations. Mussels were collected from a "clean" baseline location and transplanted into the Duwamish River and Elliott Bay for a period of one month, both during wet and dry season river-flow conditions. Mussel tissue was analyzed and chemical concentrations will be compared between transplanted mussels, ambient or wild mussels, and mussels from the baseline sampling location.

Chemical analysis of various fish and shellfish tissue was conducted on samples collected by Washington State Department of Fish and Wildlife personnel as part of their Puget Sound Ambient Monitoring Program work. Tissue was collected from English sole, quillback rockfish, Dungeness crab, spot prawn, and numerous small fish. In addition, samples of squid and benthic invertebrates were collected by King County personnel for chemical analysis. Tissue samples were resected, homogenized, and analyzed by King County personnel. All tissue collection was performed following methodologies suggested in *Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound* (PSEP, 1996).

All tissue samples were analyzed for the thirteen priority pollutant metals mentioned above in addition to butyltin isomers. Tissue samples were also analyzed for BNA compounds (including caffeine and coprostanol), PCBs, and percent lipids and total solids. Analysis of total solids and percent lipids allowed normalization of tissue chemical data to dry weight and lipid content, respectively.

Fecal coliforms were analyzed in tissue samples collected from wild mussels located near one in-river CSO. Baseline samples were collected prior to a discharge event and additional samples were collected following the discharge event. In addition to fecal coliforms, mussel tissue samples were analyzed for viruses, salmonella, and *Yersinia* bacteria.

Abundance and Diversity of Benthic Infauna

Numbers of species present in benthic sediment in an area influenced by a CSO were compared with similar data from an in-river reference area. Additional comparisons between the impacted and reference sites were made by employing standard reference species numbers and other indices developed by the Washington State Department of Ecology for Puget Sound. In addition to the benthic analysis, the sediment samples were analyzed for chemical and physical characteristics.

Sediment samples were collected near a CSO outfall and at an in-river reference station. Both sampling sites included a transect of five grab stations. Samples were collected by Striplin Associates personnel assisted by King County personnel. Sample collection followed methodologies suggested in *Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound* (PSEP, 1996) and *Recommended Protocols for Sampling and Analyzing Subtidal Benthic Macroinvertebrate Assemblages in Puget Sound* (PSEP, 1987).

In addition to the taxonomic analysis, the benthic sediments were analyzed for the physical and chemical analyses mentioned previously. This analysis provided data regarding the chemical and physical nature of the sediment in which the benthic organisms reside.

SUMMARY

Completion of the field sampling program has provided the project team with a large volume of high-quality data with which to model toxicant fate and transport in the study area as well as perform human health and ecological risk assessments, thus meeting the initial goals of the field sampling portion of the project. The field data, in addition to hydrodynamic data, have been used to successfully calibrate the toxicant fate and transport model for 19 chemicals of potential concern as well as fecal coliform bacteria. One-year model simulation runs have been completed and the output has been submitted to the risk assessment team. Ten-year model simulation runs and the risk assessments are scheduled to be completed during the summer of 1998.

In summary, during the course of the King County Water Quality Assessment project, over 13,000 analyses were performed on nearly 2,000 water, sediment, and tissue samples. Challenges to this intensive field sampling program included mobilizing field and analytical staff during storm events, development of new field and analytical methodologies, and management of sample throughput and large database.

ACKNOWLEDGMENTS

Several staff of the King County Environmental Laboratory were instrumental in the success of this sampling and analytical program, investing both time and expertise to develop new methodologies and manage the sheer volume of samples and resulting data. They include Ben Budka, Marc Patten, and Jean Power of the Environmental Services Unit, Bob Kruger of the Conventionals Laboratory, Diane McElhany of the Trace Organics Laboratory, John Rowan of the Trace Metals Laboratory, and Debbie Turner of the Microbiology Laboratory.

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SEASONAL CHARACTERIZATION OF STORMWATER QUALITY IN AN URBAN RESIDENTIAL AREA

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ABSTRACT

The Residential Stormwater Monitoring Project was initiated by the Boston Water and Sewer Commission in March of 1997. The purpose of the project was to characterize the seasonal variation in the quality of stormwater discharged from a low-density residential area. The project included precipitation monitoring, stormwater quality sampling and quantification of flows at a single manhole location for up to five storms per season for a period of one year, surface stormwater quality sampling at five gutter locations, and inspection and sampling of dry weather flows in storm drains. Based on the data collected event mean concentrations and loading estimates were calculated and compared with earlier data, and recommendations were developed for stormwater quality improvements for the project area and for future stormwater monitoring projects.

INTRODUCTION

The Boston Water and Sewer Commission is statutorily responsible for maintaining storm drainage systems in the City of Boston. The Commission currently maintains 92 major and 98 non-major storm drain outfalls. Approximately one quarter (11 square miles) of Boston is served by separate storm drains. The remainder is served by combined sewers or separate storm drains which discharge to combined sewers.

The Commission completed a two-part NPDES Stormwater Permit Application (Permit Application) and submitted it to EPA in 1993. As part of the application the Commission collected stormwater quality and flow data during a four-month period for five representative land use areas in Boston. Annual pollutant loadings were calculated based on an event mean concentration for each parameter. Inherent in the calculations was the assumption that pollutant concentrations do not vary significantly throughout the year. While this assumption is reasonable for some parameters, others may be subject to seasonal variations due to specific activities occurring within drainage areas during certain times of the year, as well as the effects of temperature and other climatic conditions on pollutant levels.

The Commission initiated the Residential Stormwater Monitoring Project in March of 1997. The purpose of the project was to characterize the seasonal variation in the quality of stormwater discharged from a low-density residential area. Low-density residential is the primary land use in the separated areas of Boston. The study area is an 84 acre area located in the West Roxbury neighborhood of Boston. The study area is part of a larger 484 acre drainage area tributary to Bussey Brook which is located in the Charles River Watershed. A small portion of the study area and most of the larger drainage area are located in the neighboring town of Brookline. The area was monitored during preparation of the Commission's Permit Application. Topography in the drainage area is relatively flat, with an average slope of five percent. Land use in the study area is primarily single-family residential with two-family houses interspersed. Of the 523 housing units in the study area, 369 or 71 percent are single-family and 29 percent are two-family. The Thomas J. Hynes Field, a public park about 6-1/2 acres in size, and the Lyndon Elementary School are also located in the study area. The average single-family home lot size is about 1/8 of an acre. Taking road surfaces, driveways and parking areas into account, as well as roof drains which are hydraulically connected to the drainage system, impervious area in the study area is estimated to be about 37 percent.

Storm drains vary in size from 10-inches in the drainage area's upper reaches to 60-inches at each of the two parallel outfalls. Theoretically, flows from the study area can discharge through either outfall. However, most of the flow discharges through one outfall due to the configuration of the drainage system and siltation in the other discharge pipe.

METHODOLOGY

To characterize stormwater runoff quality and reflect seasonal variations in weather patterns and pollutants, the Commission attempted to sample up to five storms per quarter for a period of one year. At least two of the storms sampled per quarter were to meet the representative "base case" storm criteria set forth in EPA's NPDES Stormwater Sampling Guidance Document (EPA 833-B-92-001, July 1992). For Boston the representative storm criteria were determined to be as follows:

Antecedent dry weather:	3 days (72 hours)
Rainfall:	0.4 to 1.0 inches
Duration of rainfall:	6 to 18 hours

Up to three additional storms, which did not meet the base case storm criteria were to be sampled each season under varying antecedent conditions. The storm criteria were modified for the winter season, since it was expected that much of the precipitation would be in the form of snowfall, and runoff would be in the form of snow-melt.

Flow/Precipitation Monitoring

To monitor flow in the drainage area, an automatic area/velocity flow meter was installed in the same storm drain manhole monitored during the preparation of the Commission's Stormwater Permit Application. To enable remote retrieval of data, the flow meter was telemonitored via a telephone service line connected to a nearby telephone pole. It was programmed to provide continuous readings at five-minute intervals and record precipitation in one-hundredths of an inch at all times during the project.

To measure local volume and intensity of rainfall in the study area, a precipitation monitoring station was established on the roof of a nearby establishment. The precipitation monitoring station was equipped with a tipping bucket rain gauge with a data logger and associated software. The rain gauge was programmed to operate continuously at five-minute intervals throughout the duration of the project. The rain gauge was not equipped to record accumulated snowfall.

Weather was monitored continuously throughout the project through the *INTELLICAST Boston Weather* internet web site, the NOAA weather (radio) station, and the National Weather Service.

Stormwater Quality Monitoring

The automatic composite sampler used for the project was connected to the telemonitored flow meter in order to allow remote activation during storm events. EPA's Stormwater Sampling Guidance recommend flow-weighted composite samples collected during a representative storm for the first three hours, or for the duration of the storm if less than three hours long. For this project, the decision was made to extend the compositing period to four hours in order to obtain data which were more representative of average New England storm conditions.

Composite samples collected from the sampling manhole were analyzed for total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrite/nitrate-N, ammonia-N, total kjeldahl nitrogen (TKN), organic-N, total phosphorus, chloride, and total and soluble cadmium, copper, lead, zinc and sodium. Total cyanide was analyzed during the winter quarter (January through March), since cyanide is commonly used as a road salt anti-caking agent, and soluble metals were included to enable evaluation of potential toxicity to aquatic biota. Parameters for analysis were selected based on the following criteria:

- o they were present at elevated concentrations in samples collected for the study area during the preparation of the Stormwater Permit Application (bacteria);
- o they are pollutants of specific concern in developing management controls (bacteria, solids);
- o they are pollutants of specific concern in evaluating receiving water impacts (soluble metals, bacteria);
- o they are expected to demonstrate seasonal variability in concentrations (BOD, nutrients, bacteria, solids, metals, cyanide).

Consideration was given to monitoring for pesticides. However, since all of the pesticides detected in samples collected during the preparation of the Permit Application are no longer being manufactured, pesticides were not included in the project parameters.

In addition to composite samples, grab samples were collected from the monitoring manhole to be analyzed for pH, temperature and conductivity and bacterial sampling for fecal coliform, fecal strep and *E. coli*. The grab samples were collected between one and two hours after the start of the storm to avoid skewing the data from first flush effects and to ensure contribution from tributary land surfaces. Oil and Grease (O&G) samples were collected at the outfall, not at the monitoring manhole since collection of the sample directly into the sample container, as protocol requires, could not be done without entering the manhole during wet weather. Also collected were surface runoff samples from gutters situated at five representative locations throughout the drainage area to be analyzed for fecal coliform, fecal strep and *E. coli*. The fecal strep measurement was included primarily for use in determining the fecal coliform/fecal strep (FC/FS) ratio. Two of the gutter sampling locations, the VFW Parkway site and the site at Carlson Circle, were also sampled for O&G. The purpose of this sampling was to assess the contribution of pollutants from surface runoff. Samples were collected between one and two hours after the start of the storm from the deepest part of the surface flow as it approached catch basins.

Dry Weather Inspections

Once during each project quarter, the outfall, monitoring manhole and up to 10 additional manholes in the drainage area were visually inspected during dry weather. Dry weather was defined as three continuous days with less than 0.1 inches of precipitation. Where observed, dry weather flow was measured using a portable velocity meter, and grab samples were collected for on-site analysis of temperature, pH, conductivity, chlorine (residual), copper, surfactants and phenols using a CHEMetrics storm drainage field test kit. Where sanitary sewage contamination was suspected, grab samples were collected and analyzed for fecal coliform, fecal strep, *E. coli*, ammonia-N and fluoride. These tests and further inspection of manholes and dye testing of houses in the study area by the Commission revealed twelve sanitary sewer connections to storm drains in the drainage area, eight of which were located in the study area. Two of the eight in the study area were located in the Town of Brookline. It is interesting to note that despite the sanitary sewer connections to storm drains in the drainage area, no evidence of sanitary sewage was observed at the outfall during previous monitoring for the Permit Application, nor during the course of this project.

Six of the sanitary sewer connections in the study area, including the two in Brookline, and the two sanitary sewer connections outside the study area were corrected by the beginning of the third (fall) quarter. The two remaining sanitary sewer connections in the study area required special engineering to eliminate, and thus were not scheduled for correction until after the conclusion of the monitoring project. Dry weather inspections conducted in the third and fourth quarters of the project confirmed correction of the eight sanitary sewer connections.

RESULTS/DISCUSSION

Flow/Precipitation Monitoring

Upon installation in April of 1997, the flow meter measured base flow in the storm drain at about 1.5 inches. The base flow gradually decreased over time down to about 0.2 inches by the end of the dry summer quarter, and gradually rose again to about 1 inch during the wetter winter quarter, indicating that the base flow is primarily due to residual runoff and groundwater infiltration.

On close inspection of the first quarter data, regular daily flow increases were observed which corresponded to the daytime hours, when people were most likely using water in their homes. This suggested that at least a small portion of the base flow was due to the existence of sanitary sewer connections to storm drains in the study area. Sanitary sewer connections to storm drains in the study area were confirmed during dry weather inspections and subsequently eliminated as described in the previous section.

Precipitation in Boston was significantly below average during the first three quarters of the monitoring project (April through December). For 1997 overall, average precipitation was 8.43 inches below normal. January through March of 1998 were fairly wet but very mild. Of the 54 storm events occurring during the monitoring period, only eight met all three of the storm criteria established by the Commission at the beginning of the project.

Given the lack of rainfall during the previous months and the insufficient number of storms meeting the storm criteria, the Commission decided midway through the summer quarter to modify the storm criteria in order to capture more storms events. The criteria were relaxed to include any event with more than 0.3 inches of precipitation rather than the previously required 0.4 inches, and a minimum storm duration of four hours. Antecedent conditions were reviewed on a case-by-case basis to determine the suitability of an event for monitoring.

As winter approached the Commission developed special criteria for sampling flows in the drain under varying winter conditions, i.e. after a road de-icing and sanding event or following snowpack melting. However, lack of snowfall in the winter of 1998 prevented much sampling under such specific conditions. The resultant monitoring events included two mixed precipitation events with associated deicing activity, and two winter rain storms.

Based on precipitation and flow data, runoff coefficients were calculated for all precipitation events exceeding the base case minimum precipitation volume of 0.4 inches. The event runoff coefficient was calculated as the portion of precipitation that resulted in runoff, i.e. total runoff volume divided by total precipitation volume. Total precipitation volume was calculated as the total precipitation multiplied by the land area in the study area. Runoff coefficients for this project ranged from 0.03 for a 0.97 inch precipitation event (0.52 in/hr maximum intensity) to 0.28 for a 2.74 inch precipitation event (0.03 in/hr maximum intensity). Runoff coefficients for the winter months were notably higher, possibly due to saturation of the water table or due to frozen ground. Overall the runoff coefficients were consistently lower than those calculated for the Commission's Stormwater Permit Application, even for similar size storms, and they were significantly lower that the coefficient calculated for the area based on EPA's Guidance Manual for Part 2 Applications.

Although 1997 was a very dry year, it is unlikely that this alone would account for the low runoff coefficients demonstrated in this study. The Commission attributes the differences in the runoff coefficients to the use of a different rain gauge location (in closer proximity to the study area) than was used for the Stormwater Permit Application, use of a different, more accurate flow meter, different placement of the meter probe in the drain pipe, and installation of a flow control structure in the drain pipe to improve the accuracy of low flow measurements. Since a portable velocity meter was used to confirm the accuracy of the flow meter, the coefficients calculated for this project are believed to be the most accurate.

Water Quality Data

Stormwater quality data was obtained for 10 storms during the monitoring period. This was only half of the 20 planned at the onset of the project. Of the storms sampled only two met all of the storm event criteria established for the program. Sample Mean Concentrations (SMCs) for conventional pollutants in the composite samples collected from the monitoring manhole are shown in Table 1. Event mean concentrations (EMCs) calculated for the Nationwide Urban Runoff Program (NURP) and EPA's Freshwater Acute Water Quality Criteria are included in Table 1 for comparison purposes.

The relatively large (0.84 inches) storm on November 22, 1997 was sampled twice; once within the first four hours of the storm and a second time after the storm had peaked and rainfall had begun tapering off. The purpose of this sampling protocol was to evaluate the validity of using composite sampling data collected in the first several hours of a storm event (per EPA's sampling protocol) to represent event mean concentrations applicable to the entire runoff volume for the event.

Total Suspended Solids

The storm event on August 13, 1997 exhibited elevated TSS levels in comparison to the August 20-22, 1997 event. This is likely due to the high intensity of the rainfall occurring during the composite sampling collection, resulting in more scouring of pervious and impervious surfaces.

Deicing Parameters

Sodium, chloride, total dissolved solids (TDS) and total suspended solids (TSS) were higher during the late fall and winter storm events after snow storms requiring road de-icing and salting. Cyanide was also detected in composite samples collected on January 23, 1998 and February 12, 1998 after previous storm events required roadway de-icing. Since cyanide was not detected in samples collected during the spring and summer months for the Permit Application it is believed that its presence in the runoff is limited to the deicing season.

Toxic Metals

Copper and zinc exceeded the 1986 EPA Freshwater Acute Ambient Water Quality Criteria in 40 percent and 50 percent of the samples respectively, based on total recoverable metals concentrations. However it is EPA's current policy, as stated in its October 1, 1993 "Metals Policy" memorandum, to recommend the use of the dissolved metal concentration to set and measure compliance with water quality standards, because the dissolved metals concentration more closely approximates the bio-available fraction of metal in the water column. Table 1 also lists the EPA acute toxicity criteria expressed as dissolved metals concentrations, derived using the conversion factors that were subsequently published in the EPA's "Conversion Factors for the Calculation of Dissolved Freshwater Aquatic Life Criteria for Metals" (U.S. EPA, 1995). Comparison of these adjusted criteria with the dissolved metals concentrations measured in the project indicates only one exceedance of the zinc criterion and none of the copper criterion. It should be noted however, that EPA's criteria are hardness-dependent, i.e., the toxicity of the metal is a function of the hardness (expressed as $CaCO_3$) of the water, and EPA's criteria presented in Table 1 are based on moderately hard water (100 mg/l as $CaCO_3$). As a result they may underestimate the toxicity of metals in the softer surface waters typical of New England.

Besides sodium, zinc was the only metal to demonstrate any degree of seasonal variation with the concentrations in samples collected in the fall and winter deicing seasons being higher than concentrations in the summer. Sources of zinc include automotive fluids, tire wear, metal corrosion, paint and deicing salts.

Table 1. Wet Weather Conventional Pollutant Concentrations

Analyte Reporting Units	Regulatory Limit[2]	NURP Median EMC	Sample Mean Concentration (SMC) [1]										
			4/17/97	8/13/97	8/21/97	10/25/97	10/27/97	11/1/97	11/22/97 Early	11/22/97 Later	1/7/98	1/23/98	2/12/98
Field Parameters													
PH su		NA	6.64	6.95	6.81	7.21	7.92	6.84	NA[7]	NA[7]	8.40	8.32	8.02
Temperature °C	28.3[3]	NA	19.6	19.6	10.1	10.1	9.6	12.3	NA[7]	NA[7]	7.6	4.0	6.33
Conductivity μmhos	NA	NA	830	1250	1030	1010	370	830	NA[7]	NA[7]	465	1635	1340
Total Metals													
Cd mg/L	0.0039[4]	NA	- -	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ND
Cu mg/L	0.018[4]	0.034	- -	0.019	0.015	0.019	<0.010	0.014	0.022	0.010	0.007	0.005	0.025
Na mg/L	NA	NA	- -	18.6	13.2	4.56	5.68	18.3	530	82	55.1	1730	833
Pb mg/L	0.082[4]	0.144	- -	0.028	0.034	<0.050	<0.050	0.021	0.028	0.013	0.011	0.008	0.045
Zn mg/L	0.120[4]	0.16	- -	0.096	0.046	0.11	0.052	0.212	0.139	0.064	0.036	0.095	0.144
Soluble Metals													
Cd mg/L	0.037(4)	NA	<0.005	<0.001	<0.001	<0.001	<0.001	NA	NA	NA	<0.001	<0.001	ND
Cu mg/L	0.017(4)	NA	0.013	0.008	0.007	<0.010	<0.010	NA	NA	NA	<0.005	0.014	0.006
Na mg/L	NA	NA	141	19.3	14.1	11.2	4.34	NA	NA	NA	54.9	1830	880
Pb mg/L	0.065(4)	NA	<0.020	0.006	<0.020	<0.020	<0.020	NA	NA	NA	<0.005	<0.05	ND
Zn mg/L	0.117(4)	NA	0.065	0.057	0.034	0.057	0.07	NA	NA	NA	0.042	0.126	0.089
Other parameters													
Chloride mg/L	NA	NA	370	27.1	19.4	7.0	7.0	33.0	651	140	95	3420	1610
BOD mg/L	NA	9	- -	9.76	4.62	23.4	11.0	8.1	22.8	11.4	9.3	4.86	7.41
COD mg/L	NA	65	52.8	75.3	40	50.3	34.5	50.8	75.5	38.5	31	29.0	87.0
Cyanide mg/L	0.022										<0.01	0.062	0.079
NO_2-N mg/L	NA	NA	ND	0.06	0.054	<0.03	<0.03	<0.03	0.031	<0.03	<0.03	<0.03	0.055
NO_3-N mg/L	NA	0.68[6]	1.82	1.01	0.878	0.468	0.276	0.523	0.497	0.622	0.436	0.223	0.437
Ammonia-N mg/L	30[5]	NA	0.647	0.914	0.336	0.468	0.204	0.492	0.401	0.172	0.108	0.429	0.539
TKN mg/L	NA	1.50	1.9	2.02	0.92	1.3	1.72	27.2	1.75	2.62	0.85	0.65	1.60
Organic N mg/L	NA	NA	1.25	1.11	0.584	0.832	1.52	26.7	0.209	0.069	0.742	0.221	1.06
Total P mg/L	NA	0.33	0.352	0.479	0.236	0.329	0.23	0.324	0.277	0.147	0.119	0.093	0.356
o-Phosphate mg/L	NA	0.12	- -	0.165	0.196	0.225	0.174	<0.05	0.196	0.096	0.052	<0.05	0.056
TDS mg/L	NA	NA	826	142	130	40	40	96	1,300	270	178	5810	2540
TSS mg/L	NA	100	41	55	12	28	11	37	40.0	10.0	12	25.0	91.0

Notes:
(1) Concentrations based on flow-weighted composite sample
(2) Based on EPA Freshwater Acute Water Quality Criteria (1986) and adapted for dissolved metals (EPA 1995)
(3) Massachusetts Surface Water Quality Standards for Class B Inland Waters
(4) Based on assumed hardness = 100 mg/L
(5) Based on pH = 6.5
(6) Results presented as combined nitrate/nitrite
(7) Field equipment malfunctioned, no results available.

SMC = Event Mean Concentration
NA = Not Available or Not Analyzed
ND = Not Detected
NC = Not Calculated

With respect to individual metals concentrations, cadmium was not detected in any of the runoff samples and does not appear to pose a threat to receiving water quality.

The SMCs of lead measured were significantly lower than those reported in the NURP study and, to a lesser extent, lower than the concentrations measured in the same drainage area during preparation of the Permit Application five years earlier. This trend is consistent with other more recent stormwater investigations and is directly attributable to the decreased use of lead in gasoline. None of the SMCs measured exceeded the acute toxicity criteria for lead.

Nutrients

Concentrations of nitrogen and phosphorus were generally comparable to the NURP EMCs and the Permit Application data for the drainage area. Except for the generally higher concentrations of these parameters in samples collected on August 1, 1997, seasonal variations were not significant. It is possible that the higher concentrations on that data were attributable to summer landscaping activities. However, the conditions were not repeated in any other monitoring event during the spring or summer.

In comparison to other events monitored, high levels of TKN and organic nitrogen were observed in the composite sample collected on November 11, 1997. The concentrations of other forms of nitrogen or of associated parameters were not unusual in this sample. No explanation is evident for this one incident of high TKN and organic nitrogen.

Bacteria

Table 2 shows the results of the wet weather bacterial monitoring at the monitoring manhole and at three of the five of the gutter sampling locations. The results of the bacteria sampling conducted during the storm on November 22, 1997 were not included since the data produced was highly inconsistent, and discussions with the laboratory director indicated that the samples may have been mislabled.

Table 2. Wet Weather Bacterial Concentrations

	4/17/97	8/13/97	8/21/97	10/27/97	11/1/97	1/7/98	1/23/98	2/12/98
Monitoring Manhole								
Fecal Coliform (#/100 ml)	37,000	50,000	150,000	4,000	27,000	11,000	800	900
Fecal Strep (#/100 ml)	2,300	1,600	23,000	700	6,100	4,700	5,500	2,400
E. coli (#/100 ml)	NA	40,000	21,000	1,200	19,000	6,000	100	800
Hynes Field								
Fecal Coliform (#/100 ml)	30,000	90,000	NS	20,000	140,000	NS	NS	NS
Fecal Strep (#/100 ml)	74	3,000	NS	5,000	1,000	NS	NS	NS
E. coli (#/100 ml)	NA	60,000	NS	9,000	1,000	NS	NS	NS
Bonad Road								
Fecal Coliform (#/100 ml)	7,000	23,000	NS	1,100	4,000	NS	NS	NS
Fecal Strep (#/100 ml)	600	5,200	NS	200	300	NS	NS	NS
E. coli (#/100 ml)	NA	3,700	NS	500	4,000	NS	NS	NS
Carlson Circle								
Fecal Coliform (#/100 ml)	1,200	11,000	NS	7,000	4,500	NS	NS	NS
Fecal Strep (#/100 ml)	91	800	NS	2,000	1,400	NS	NS	NS
E. coli (#/100 ml)	NA	2,600	NS	4,000	500	NS	NS	NS

Notes: (1) Concentrations based on grab samples
NA = Not Available or Not Analyzed

The Massachusetts Class B Water Quality Standard for fecal coliform bacteria is a log mean of 200 colonies/100 milliliter (ml). Massachusetts does not have a standard for either fecal strep or *E. coli.* However, the EPA recommended criterion for freshwater bathing beaches is 235 colonies *E. Coli* organisms per 100 ml. In urban runoff, fecal coliform concentrations frequently exceed water quality standards, with typical warm weather concentrations in the 10,000 to 100,000 colonies per 100 range (NURP, 1983). The medan fecal coliform concentration for all the NURP sites was around 21,000 colonies per 100 ml.

As indicated by the data presented in Table 2, fecal coliform concentrations measured in the study area were consistent with the NURP data, although they frequently exceeded the Massachusetts standard. The fecal coliform concentrations measured during preparation of the Permit Application were significantly lower. However, it has been concluded that the Permit Application bacterial data were subject to laboratory error.

Concentrations of bacteria were significantly higher during the warmer summer months, as compared to samples collected during the colder fall and winter months. This was not surprising since it is known that bacteria will survive longer under warm conditions. Antecedent conditions also appear to impact bacterial concentrations, since the two events preceded by only one day of dry weather (October 27, 1997and January 7, 1998) had the lowest concentrations relative to the season. The highest concentrations of bacteria were observed in the surface grab samples collected at the Hynes Field. Observations made during visits to the park and conversations with local residents indicated that the park is a common destination for dog owners in the neighborhood. This strongly suggests that pet waste is a major contributer of bacterial contamination to the stormwater runoff in the project area.

Oil and Grease

Higher concentrations of oil and grease were observed at the surface location which receives runoff from the VFW Parkway as compared to the Carlson Circle site. The VFW Parkway is a highly traveled, four-lane roadway while Carlson Circle is a residential side street. The concentration of oil and grease was below detection in the samples collected during the two events with only one day of antecedent dry weather (October 27, 1997 and January 7, 1998). This is likely due to most of the accumulated oil and grease O&G having already been washed off the road surfaces.

Pollutant Loadings

The two sets of samples collected at different phases of the same storm on November 22, 1997 yielded significantly different results. Pollutant concentrations were consistently lower in the composite sample collected later in the storm. Only nitrate and TKN increased in the later sample, possibly indicative of nitrification processes taking place. These results indicate that the use of composite data from the first several hours of a larger storm event to represent the event mean concentration could result in an overestimation of pollutant loadings due to the more dilute concentrations which occur later in a storm event.

FINDINGS/CONCLUSIONS

Runoff coefficients calculated for this project and for the Commission's Permit Application were significantly lower than the value calculated using the method recommended in EPA's Guidance Manual for Part 2 Applications. Since the runoff coefficients calculated for this project were based on metered flows, they are believed to be the more accurate, thus suggesting that the EPA method overestimates runoff coefficients, particularly for smaller storms.

It appears that EPA's storm criteria are too restrictive for the Boston area. Due to weather conditions few of the storms (only eight of all fifty-four) occurring during the monitoring period met the initial storm criteria of 0.4 to 1.0 inches of rainfall, 6 to 18 hour storm duration and 72 hours of antecedent dry weather. Of the ten storms sampled, only two met the initial storm criteria. It should be noted however, that 1997 was a particularly dry year in Boston and precipitation was much lower than average.

Seasonal variations in pollutant concentrations occurred most frequently in parameters that are associated with winter deicing practices.

Comparison of the two data sets collected on November 22, 1997 indicated that the use of composite data from the first several hours of a larger storm event to represent the event mean concentration could result in an overestimation of pollutant loadings since significantly more dilute concentrations occur later in a storm event.

Although the bacterial concentrations in samples collected from the monitoring manhole and the gutter locations were similar to concentrations reported in NURP, most samples exceeded Massachusetts' water quality standards for Class B waters. While some of the bacterial contamination in the samples taken from the monitoring manhole can be attributed to the influence of the two remaining sanitary sewer connections to upstream drains, it is unlikely that the surface runoff grab samples were contaminated with human waste. Thus it appears that the Massachusetts standard for Class B waters is unrealistically high for urban stormwater runoff.

The highest concentrations of bacteria were measured in the surface grab samples collected at the Hynes Field, where local residents are known to bring their dogs. Thus, it was concluded that the primary source of bacterial contamination in the drainage area is urban runoff that had come into contact with deposited pet waste.

The FC/FS ratio for all of the bacterial samples collected in this program were greater than unity, and most were greater than four. Ratios greater than four typically suggest human sources, while those less than 0.7 indicate non-human (animal) sources. Since it is unlikely that the surface runoff grab samples collected in this program were contaminated with human waste, the data suggest that the FC/FS ratio is not a good indicator of bacterial sources in stormwater.

The concentration of oil and grease were below detection in the samples collected during two events that had only one day of antecedent dry weather October 27, 1997 and January 7, 1998), indicating that the previous storms had washed all the accumulated oil and grease off the road.

RECOMMENDATIONS

Stormwater Management

The Boston Public Works Department (PWD) is responsible for roadway de-icing and street cleaning in the City of Boston. The Commission will encourage the PWD to closely monitor and modify its de-icing practices and minimize use of de-icing agents and sand. PWD should also be encouraged to conduct more frequent street cleaning in the study area to remove street deposited automobile fluids, oil and grease, sediments, leaves, litter and accumulated pet waste.

The City of Boston's Animal Control Unit is responsible for enforcing the city's dog fouling ordinance, Section 16-1.10A of the Boston City Ordinances. Fines are $50.00 for failure to remove dog waste. The Unit should be encouraged to upgrade its surveillance and enforcement efforts in the study area.

The City's Parks Department has already installed signs at Hynes Field to inform residents of the repercussions of failing to clean up after their pets. In addition the Commission has asked the Parks Department to consider installing mutt-mitt dispensers to assist dog owners in collecting wastes.

The Commission should encourage town officials in Brookline to implement activities similar to those described above to improve stormwater quality in the drainage area which lies in Brookline.

Future Monitoring

The Commission was surprised at the initiation of the program to discover several sanitary sewer connections to the storm drains in the study area, especially since there had been no evidence of sanitary sewage contamination in the monitoring manhole or at the outfall during preparation of the Permit Application. In the future dry weather inspections of manholes in any drainage area to be monitored will be conducted prior to initiating the monitoring program.

Strict adherence to the criteria established by EPA restricted the number of storms suitable for sampling. More flexibility in the storm criteria established for future programs must be allowed, if a sufficient data base is to be developed.

The results of the dual sampling on November 22, 1997 suggest that the use of composite data collected during the first several hours of a larger storm event to represent the event mean concentration could result in an overestimation of pollutant loadings. In order to obtain composite samples that are more representative stormwater quality for the entire storm event, composite samples should be collected over a longer duration.

Future stormwater monitoring programs should include analysis for soluble metals, since EPA's current policy, is to recommend the use of the dissolved metal concentration to set and measure compliance with water quality standards. In addition the hardness of the stormwater should be monitored during future sampling, since the toxicity of the metals is a function of its hardness.

Additional sampling under winter conditions should be conducted to evaluate the effect of various conditions on stormwater quality, i.e. after road de-icing and sanding events, following extended periods with snowpack and during melting. Additional monitoring for Cyanide should also be conducted to obtain a more complete database.

ACKNOWLEDGMENTS

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WATER QUALITY MONITORING FOR THE DETERMINATION OF EFFECTS OF COLLECTION SYSTEM DISCHARGES ON RECEIVING WATERS

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ABSTRACT

Water quality monitoring programs have recently been completed in two metropolitan areas within the United States. One program was designed to assess the effects of sanitary sewer overflows (SSOs) on receiving waters. The other program was to determine the impact of combined sewer overflows (CSOs) on a local river. The experiences during these major water quality monitoring programs have proved that: (1) Detailed planning prior to the beginning of the program will minimize logistical problems; (2) The mobilization of sampling staff for a wet weather event when multiple entities are involved can wreak havoc on the program; (3) Several meetings with laboratory staff prior to the program can help set the proper course for laboratory analyses during the course of the program; (4) Constant reliability checks are necessary to prevent instrument drift and to assure that representative data are being collected; and (5) Opportunities for innovation can lead to pleasantly surprising results. This paper will relate in more detail the lessons learned during the course of these sampling programs. The paper will also present techniques and innovations developed for collecting and analyzing water quality data.

KEYWORDS

monitoring, sampling, SSO, CSO, overflows, DO

INTRODUCTION

Many programs repeat common mistakes, which lead to the collection of large quantities of data that provide very little benefit. This paper will serve as a guide for municipalities who are in the process of beginning a water quality monitoring program. An outline will be presented for the design and implementation of a monitoring program which ensures the collection of sufficient data to adequately characterize both the collection system discharges and the receiving water impacts. Additionally, techniques for reviewing and assessing the quality of the data collected will be described. Data analysis methods currently in use in the United States and abroad are compared, and several emerging technologies are discussed.

METHODOLOGY

Before undertaking any activity to mitigate collection system discharges into receiving waters, it is imperative that the effects of those discharges on the receiving waters are understood. A well designed and executed water quality monitoring program can help engineers assess these effects. Figure 1 displays a flow chart for designing a water quality program.

Program Design

The first step in the design of a monitoring program is to define the goals of the program: What information do you want to obtain from the monitoring program? The answer to that question will determine the level of detail in your subsequent monitoring program, and the type, accuracy, and frequency of data to be collected. Other factors in determining the objectives of the monitoring program include:

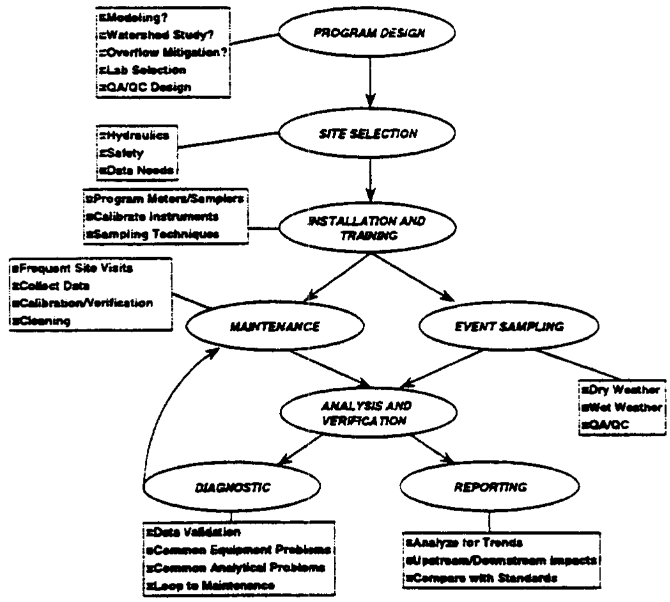
- State and local regulations
- Designated uses of receiving waters of interest

Defining the goals of a water quality program lays the groundwork for determining the components of the sampling program. A defensible monitoring program will have, at a minimum, the following components:

- Dry weather sampling,
- Wet weather sampling, and
- Continuous water quality monitoring.

Figure 1

WATER QUALITY MONITORING PROGRAM



Dry weather sampling determines the background conditions in the receiving waters. Wet weather sampling in the receiving waters and at the points of discharge from the collection system will determine the system response to storm events. Continuous water quality monitoring, primarily for dissolved oxygen (DO) and temperature, will provide useful data on the health of the receiving waters during both dry and wet weather conditions.

During this planning process, it is important to look for opportunities for innovation. For example, the CSO monitoring program used both biological monitoring and sediment monitoring data to contribute to aspects of the project objectives. Biological monitoring was performed to address regulatory issues and requirements for their system. Both lab and in-stream toxicity tests were performed to determine acute and chronic effects of CSO discharges. Sediment sampling assessed metals in the receiving water. Sediments from both the CSO structures and the receiving waters were analyzed for the same parameters to try to identify potential contamination resulting from CSO discharges. The use of these types of analyses can provide a more complete picture of the monitored system's response to wet weather discharges.

Another innovation was the use of long-term dissolved oxygen monitoring. In both the CSO and SSO programs, continuous water quality monitors were employed to show the effects of overflows on receiving waters. In the SSO program, the DO probes were installed and maintained for nearly six months. The data collected from these meters indicated that dissolved oxygen (DO) concentrations at less than the 5 mg/L state water quality standard were not caused by SSO discharges but by the diurnal fluctuations in dissolved oxygen. Further, there was no measurable response of the receiving water systems' monitored DO during storm events where SSO discharges were occurring.

Finally, QA/QC protocols for the water quality monitoring program will ensure that all samples collected are representative of the waters they were collected from and that the quality of the data is quantified. The QA/QC program should include both a field sampling component and a laboratory component to ensure a high degree of confidence in the data collection and analysis. Sampling QA/QC protocols typically call for:

- Field blanks to evaluate whether there was any cross contamination occurring that was attributable to sampling equipment or practices,
- Field duplicates to evaluate the sampling process with respect to the repeatability of the results,
- Trip blanks to measure cross contamination during transport, field handling, and storage, and
- Equipment blanks to measure the adequacy of the decontamination of sampling equipment after its use.

Because sample analysis is expensive, it is common practice to collect a full compliment of blanks, and then only analyze the field blanks. If the analysis indicates no problems with the field blanks, then the other blank samples may be discarded (Keith).

Site Selection

Once the goals of the monitoring program are clearly defined, the site selection process can begin. Often monitoring sites are located in a haphazard manner, leading to installations which are difficult to sample or which are not strategically located to meet the goals of the program. Another common flaw is to begin overflow monitoring without an accurate understanding of the collection system hydraulics, especially when monitoring overflows from sanitary sewers. A detailed understanding of the collection system topology is required in order to locate sampling points where they will best collect data to meet the defined goals. Key hydraulic points such as pump stations and diversions should also be taken into consideration, as these elements can have a significant effect on the monitored hydraulics and the discharge quality. Local knowledge of chronic problem areas can also assist the engineers in planning the monitoring program.

The final step in the site selection process is to perform field investigations to determine the adequacy of the selected sites. The adequacy of a sampling site is based on three factors:

- The data needs of the monitoring program,
- The feasibility of sampling and flow measurement, and
- The sampling crew safety concerns.

In order to quantify total loads from overflows and in receiving waters, accurate flow data is required in conjunction with quality monitoring throughout the event. Keep in mind that, for most analyses, it is important to characterize *relative* differences; the actual flow rate or volume is not as important. Hydraulic factors to take into consideration when assessing the candidate sites are siltation or heavy debris buildup in the overflow pipe, complex hydraulics such as 90-degree bends or multiple inflows in receiving water sites, and pump station influence. The use of automatic flow measurement equipment should be investigated at the candidate locations. This can significantly improve the quality of the data collected while minimizing the staff necessary at each location. Receiving water flow data can be obtained from USGS gaging stations located near the monitoring sites. Automatic flow meters were successfully applied at all stream monitoring sites in the SSO monitoring program.

Consideration should also be given to sampling logistics when determining monitoring locations. Most sampling programs involve coordinating with a large field staff, analytical laboratory staff, and the weather. Since the concern of most monitoring programs is wet weather water quality, it is important that sites are selected such that sampling teams can be notified and respond in time to sample the entire event. Clustering sites can allow the use of one team to sample a number of sites, provided the sample intervals are adequately spaced (e.g., half-hour sample intervals). Sites should be located within a short drive of the lab(s) in order to minimize travel time and ensure that samples meet the required holding times.

Staffing

Teaming with client and even regulatory agency staff can provide unexpected benefits and can contribute greatly to the success of a sampling program. The obvious benefit of using these groups is the cost savings in the overall program, as they will minimize the reliance on in-house staff. Even more important, however, is the sense of ownership and cooperation achieved when working with client staff, and also with regulatory agency representatives. Involving state or local agency personnel provides an excellent opportunity for them to observe the actual sampling techniques and conditions. During the SSO program, members of the state regulatory body participated in field staff training and actually mobilized for a number of sampling events. When presenting the results of the program, the agency staff had a better understanding of how the data was collected, and the actual site locations and conditions under which the data were collected.

Similar teaming was performed with the state regulatory agency during the CSO program. Biological sampling as part of the CSO study was tied in to an existing study being performed by the state agency. This resulted in the sharing of data, and sampling was actually split between the client staff and the agency staff. The result was a greater spirit of cooperation between the client and the regulatory agency.

Teaming with client staff can also be an educational experience. The client provided nearly 75 percent of the staff for the CSO sampling program. This was originally set up as a cost saving measure; however, it led to a greater understanding of the system and its effects on the receiving waters by the client staff. A senior staff member actually mobilized and collected samples at a CSO outfall.

The mobilization of sampling staff for a wet weather event can wreak havoc on the program. This is particularly vexing when multiple entities are involved. For instance, the CSO sampling program required the consideration of the union call-out procedures of the City staff. Early in the SSO sampling program, field sampling performed by an environmental sampling services firm limited the flexibility that exists when using your own staff or sub-consultants. In either case, make sure that call-out procedures and points-of-contact are clearly defined *before* beginning the monitoring program, and are documented so that all parties have a clear understanding of their responsibilities and expectations.

Finally, involve the contract laboratory with the sampling effort early in the program. Lab staff can be used as runners for sample pick-up. In the SSO program, the lab provided space onsite for sampling equipment, and served as the staging area for all sampling events. This type of service ensures "buy-in" in the program by the lab staff.

Installation and Training

Prior to the beginning of the sampling program and after final site selection, all monitoring locations should be visited and prepared for the upcoming sampling events. Staging areas should be defined and clearly marked to assist the sampling teams. Because receiving water sampling typically occurs at bridge crossings, the location where the samples are to be taken should be identified with a mark on the bridge rail.

Corresponding flow measurements will be necessary at the wet weather sampling locations. Most flow measurements can be determined by using a portable velocity meter; however, it may be possible at some locations, particularly the overflow locations, to install automatic flow measurement devices. If manual flow measurements are performed at the receiving water monitoring sites, measurement points along the cross-section of the channel should be clearly marked on the bridge rail. Regardless of the flow measurement technique in the receiving waters, full surveys of the cross-section will need to be completed in order to define the geometry of the channel.

Any equipment such as automatic samplers and flow monitors must be installed before training of the field crews. This equipment can greatly assist in the collection of wet weather data by providing a much more consistent data set than can be achieved using human labor. The sampling requirements for bacteria usually do not permit the use of automatic samplers to collect samples during the wet weather events. However, in the SSO monitoring program, automatic samplers were used successfully to perform the sample collection. Bacteria requirements were addressed through the use of selective grab samples during the course of the event.

Training sessions in proper sample collection, handling and submission, and general field procedures must be conducted for all field staff. Specific emphasis should be placed on QA/QC issues as well as upon health and safety. All field crews should receive additional training in instrument calibration, receiving water sampling, and overflow sampling. As part of the training for the SSO sampling program, field crews mobilized to their actual monitoring site and performed many of the functions that would be done during a sampling event. This gave field crews the opportunity to:

- Get to know their assigned sites,
- Become familiar with the SOPs and sampling techniques, and
- Become comfortable with all procedures and functions that would need to be performed during an event.

Field crews should be provided with a field manual as part of the training effort for ready reference. The manual contains Standard Operating Procedures (SOPs) for all facets of field work on this project. The field manual serves as an on-site trouble shooting tool if the sampling team has a question about which parameters to sample for and when, how to calibrate the DO meter, etc. Sampling and equipment operation SOPs present the field protocols in simple, "cookbook" procedures. These SOPs provide the field staff with guidance while performing all functions of the sampling program. At a minimum, the field manual should contain the following items:

- Definition of wet or dry weather sampling event (i.e., 72 hour period of dry weather followed by threshold rainfall amount to qualify for wet-weather event; 72 hour period of dry weather to qualify for dry-weather event).
- Step-by-step procedures for collecting, documenting, storing, and transferring samples from stream and overflow sites.
- Timetable for sample collection during sampling events. This will include sampling frequency, parameters to be sampled for, and frequency of blank and duplicate submission.
- Calibration and maintenance of field instrumentation.
- Decontamination procedures for sampling equipment and instrumentation.
- Health and safety issues including protective clothing and equipment, emergency procedures, the phone number and route to the nearest hospital, and a list of phone numbers of project management personnel.

Monitoring and sampling activities present a variety of potentially hazardous situations. Safety protocols should be developed and included in the field manuals to present procedures and required equipment that are to be implemented to minimize this potential. These protocols can include all applicable company, local, state, or federal regulations. However, it is the responsibility of each individual worker to comply with all applicable regulations. All staff involved in the monitoring program should read and understand these procedures prior to commencing work.

Routine Maintenance

Routine maintenance requirements will vary depending on the scope of the monitoring program and the type (if any) of equipment utilized. Most monitoring programs will use continuous monitors for DO and temperature as well as flow meters in the monitored overflows and sometimes in the receiving waterbodies. Continuous monitoring relies on sensitive equipment installed in a hostile environment. Constant reliability checks are necessary to prevent instrument drift and to ensure that representative data are being collected. Typical maintenance activities include:

- Frequent site visits to ensure automatic equipment operation and to collect data,
- Routine calibration and verification of probes and flow meters,
- Periodic review of sampling techniques.

During any site visit, field data should be collected to compare with the recorded data. The comparison of field measured data to the continuous probes is used to indicate drift in the measurement of dissolved oxygen occurring in continuous monitors. Possible causes for observed drift may include build up of bacterial growth on the sensor membrane or low batteries. However, a rigorous maintenance schedule adhered to throughout the deployment of the monitors can control and enhance the operation of the continuous probes. Monitor locations should be visited and cleaned twice a week. Monitors should be calibrated and the membranes replaced every two weeks. Note that membrane wear is more likely to occur when the sondes operate in water temperatures in the 25-30° C range.

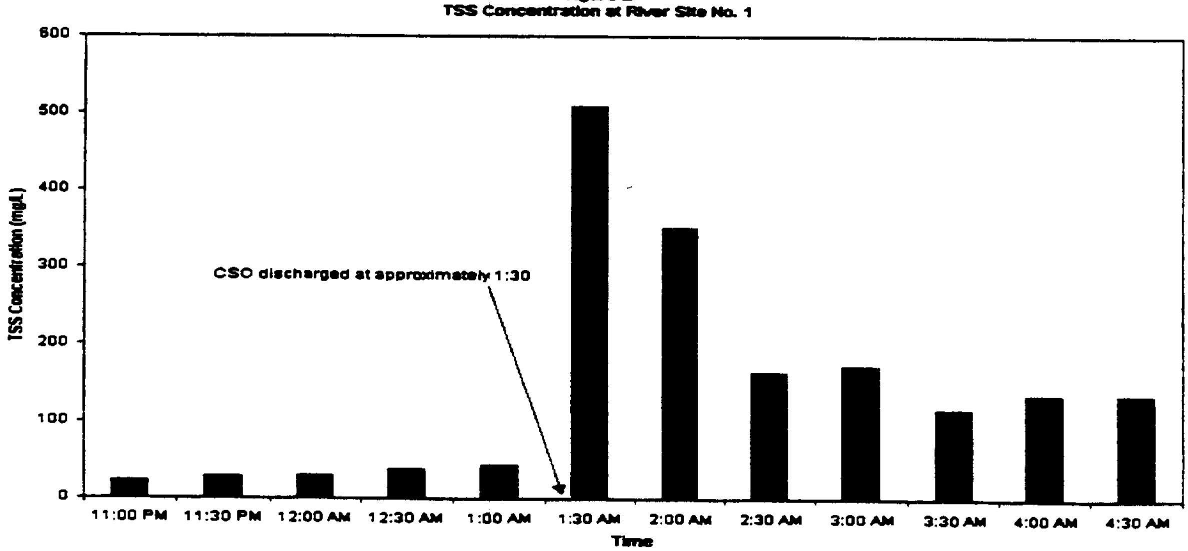
Data collected from any equipment should be frequently reviewed during the course of the program. This will assist in the detection of potential problems early in the program so that corrective action can be taken. In many cases, alternative methods of obtaining data may need to be explored due to particular site conditions.

Event Sampling

Because of the small number of samples and the flexible collection time, dry weather sampling requires only one team of two people. However, wet weather sampling requires many more samples as well as flow measurements. Therefore, sampling teams of two people for each of the monitoring sites should be used whenever possible.

Monitoring programs often rely on composite samples or post-storm event samples for stream wet weather response characterization. Experience gained during both the SSO and the CSO sampling programs proved that discrete samples taken before, during, and after the storm event provide a complete picture of stream response as well as overflow characteristics. Figure 2 displays a storm event pollutograph (monitored concentration versus time) at a receiving water sampling location monitored during the CSO program. As can be seen, the full response of the system can be analyzed using this sampling technique. Composite samples or post-storm event samples would have masked this response pattern, which may ultimately lead to the under-design or over-design of overflow control measures.

Figure 2
TSS Concentration at River Site No. 1



During each wet weather event, every sample location will have a unique sample matrix listing all samples to be collected. An example of a receiving water sample matrix is shown in Table 1. This matrix assists the sample teams in collecting all samples and completing all measurements. As the sample team collects each sample, that box of the matrix is checked, and the time is recorded. The field supervisor for each event will monitor sample times throughout the event.

Detailed field notes should be taken for all sample events. Obvious observations often become very important later on in a study. Any unusual or atypical conditions must be noted. Standard field forms can be developed for each site, and should include at a minimum:

TABLE 1
EXAMPLE SAMPLE CHECKLIST

Receiving Water Sample Location												
Event Begin Time:			Event End Time:									
				In-Stream Measurements								
Number	Time	Discrete Sample	Fecal Grab	DO			Temp			pH		
1	0											
2	30											
3	60											
4	90											
5	120											
6	150											
7	180											
8	210											
9	240											
10	270											

- Date and time of sample, and sample station identification
- sample preservation
- date of last rainfall
- name/initials of sampler
- water and air temperature
- noticeable odors, oil sheens, water color, etc.

Analysis and Verification

Review and evaluate analytical data immediately upon receipt from the lab to facilitate corrective actions if any were deemed necessary. Specific QA/QC screening procedures that should be followed as part of the data review effort include:

- Field blank data review to ensure that field blanks do not exhibit concentrations greater than the detection limit for the parameter being tested.
- Duplicate sample review to ensure that duplicate samples have reported concentrations within 25% of each other.
- Range checks to evaluate whether observed concentrations are within expected range.
- Internal consistency checks (e.g., TKN>NH_3, BOD>CBOD, and dissolved oxygen < saturation).

Blank sample results give an indication of any contamination that may have occurred during the sampling process. The relative percent differences between results of duplicate samples provide an indication of analytical precision. Range checks provide a comparison of monitored data to historical data. Internal consistency checks provide an indication of the quality of the analytical procedure followed by the lab.

It should be noted that these criteria should be defined at the beginning of the monitoring program. Further, there may be instances where data not meeting the criteria stated above would still be valid, useable data. For instance, monitored dissolved oxygen concentrations can exceed expected DO saturation values for a given temperature where the streams monitored are highly productive and experience exposure to sunlight.

If any of the data points fail to pass the above screening level checks, the data in question should be investigated. The investigation of failed data points includes at a minimum:

- Review field notes for possible explanation of the anomalous result.

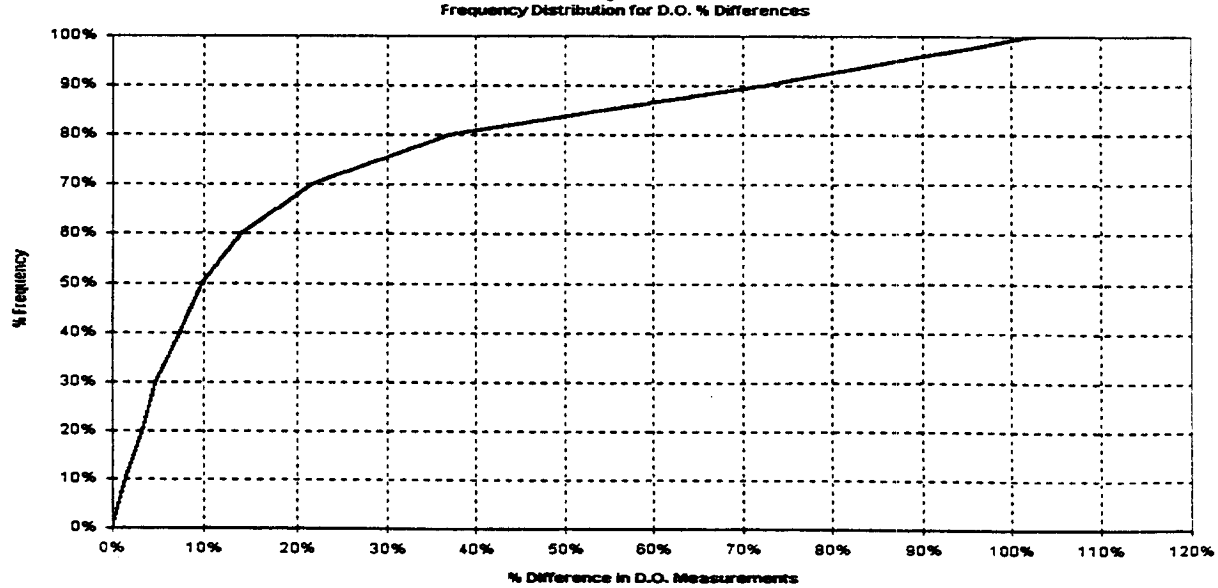
- Check for transcription error. Was the sample properly identified in the field notes, on the chain of custody, and on the lab report?
- Check with the laboratory for:
  - ⇒ Reporting error - was the result correctly transferred from bench sheets to report?
  - ⇒ Sample ID - Was the sample properly identified during the analysis?
  - ⇒ Equipment performance - did the equipment used for analysis achieve acceptable performance criteria?

If the investigation reveals any questionable results on the part of the lab, a re-analysis should be requested for the parameter in question. Any questionable results will be flagged so that future analyses are conducted with an awareness of potential problems associated with that data point(s).

Figure 3 presents a typical technique for assessing the operation of continuous dissolved oxygen probes. The figure displays a frequency distribution for the differences between field-measured and monitor-measured dissolved oxygen observations. This type of analysis can provide an indication of the reliability of the continuous monitor. By maintaining data such as this on a routine (typically weekly) basis, staff can quickly detect potential equipment problems and can help guide the routine maintenance of the sondes.

Frequent analysis of the analytical results is also recommended. Be sure to get a fast turnaround time from the laboratory, as this can affect future analyses. Figure 4 presents a technique for reviewing analytical sampling results. This figure displays the relative percent difference (RPD) versus the average monitored constituent concentration. The RPD value represents the percent difference for duplicate sample results and provides an indication of analytical precision. As can be seen on Figure 3, the greatest RPD values are at the lowest observed concentrations. This may be of concern, depending on the nature of the monitoring program. However, if the goal is to accurately quantify when high concentrations are occurring, then this graphic indicates that analytical precision is greater at the higher concentrations, thus giving greater confidence in those results.

Figure 3
Frequency Distribution for D.O. % Differences



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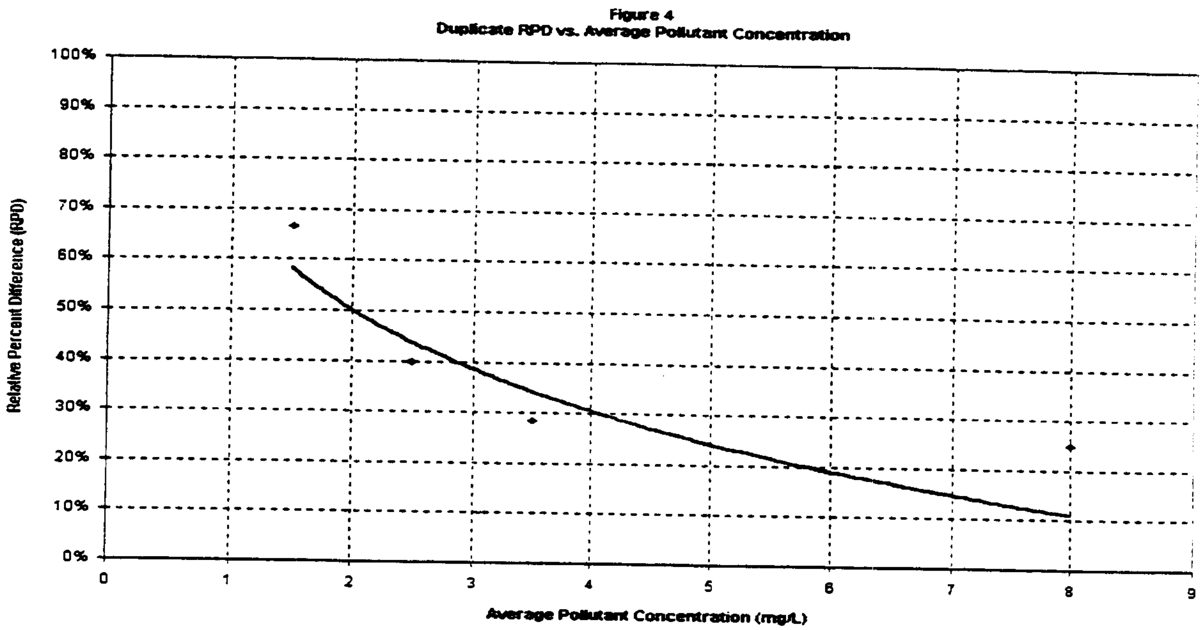
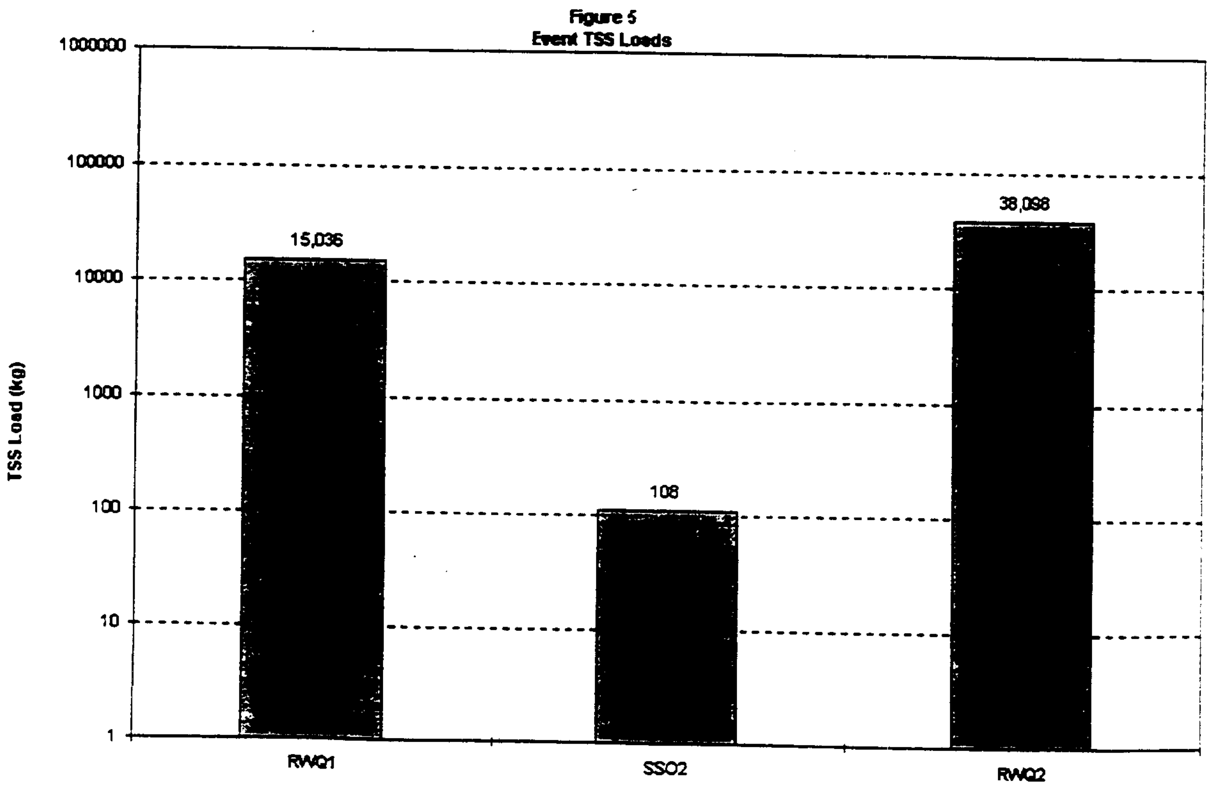


Analysis of the discrete monitoring data from both the receiving waters and the overflow discharges also provides some insights. Comparisons of upstream and downstream receiving water monitoring data can indicate whether overflows actually effect the receiving water quality. Figure 5 shows an example of this type of analysis.



Note that the data displayed in Figure 5 is on log scale. This was done so that the comparatively small SSO loads would show when compared to the receiving water loads. The monitoring data displayed in

Figure 5 indicate that, compared to the downstream site (RWQ2), the SSO loads represent less than 0.5 percent of the TSS loading. Further, the graph indicates that SSO loads are less than 0.5 percent of the increase in load from the upstream site (RWQ1) to the downstream site.

CONCLUSIONS

The experiences during these major water quality monitoring programs have provided the following insights:

Plan Ahead: Detailed planning prior to the beginning of the program will minimize logistical problems. During the SSO program, detailed standard operating procedures (SOPs) were developed. During a dry run session, sample crews mobilized and sampled according to the SOPs.

Logistics Can Kill: Staffing of a sampling program can make or break it. Use the opportunity to build relationships with client and regulatory agency staff. The CSO sampling program effectively involved staff from both groups early and often, which led to benefits at the end of the program. Note that mobilization of sampling staff for a wet weather event can wreak havoc on any program, but especially when multiple entities are involved. For instance, the CSO sampling program required the consideration of the union call-out procedures of the City staff.

Know Your Laboratory: Do not assume the laboratory understands the goals of your program or the nature of the samples that they will be receiving. Several meetings with laboratory staff prior to the program can help the laboratory to determine proper detection limits for the analyses as well as plan for the necessary dilutions. Be sure to get a fast turnaround on wet weather lab results, as this can affect future analyses.

Maintain Equipment: Continuous monitoring for DO and temperature relies on sensitive equipment installed in a hostile environment. Constant reliability checks are necessary to prevent instrument drift and to assure that representative data is being collected.

Look for Innovation Opportunities: The CSO program performed sediment sampling in both the receiving river and in the collection system. These comparisons provided useful insights into the contribution of metals from the CSOs. The SSO program used continuous dissolved oxygen monitors in conjunction with discrete overflow monitoring data to show that SSO discharges were not responsible for the non-attainment of the DO water quality standards.

Analysis: Use upstream and downstream monitoring sites to assess the effect of overflows on receiving waters. Comparisons made between monitored overflow loads and monitored receiving water loads can provide insight into the receiving water response and the overall effect of overflow discharges. For example, monitoring during the SSO program revealed that SSO discharges represented less than one percent of the monitored loads in the receiving waters.

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DYE DILUTION TESTING IN THE GREATER DETROIT REGIONAL SEWER SYSTEM- LABORATORY INVESTIGATION AND FIELD SCREENING TECHNIQUES

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ABSTRACT

Evaluation of flows entering the Detroit Water and Sewerage Department (DWSD) collection system from outlying suburban areas requires high quality continuous flow monitoring at a number of key inflow locations. As part of a large scale collection system management project, the method of dye dilution was selected to investigate the accuracy of existing flow meters and evaluate new meters installed under the project. The dye dilution method for flow rate estimation involves the addition of a small, constant stream of fluorescent dye into a sewer and measurement of dye concentration at a downstream location after the dye has been thoroughly mixed across the sewer cross section. A mass balance calculation on the injected dye can then be used to determine the flow rate in the sewer.

This paper describes results of a detailed laboratory investigation and field implementation of the fluorometric dye testing technique. In particular, the potential for interference due to abrupt changes in suspended solids and background fluorescence was observed, indicating the need for monitoring of suspended solids in virtually all field testing scenarios. A field technique for flagging potential interference by continuous monitoring of light absorbance at the rhodamine WT excitation wavelength was developed.

A comprehensive error analysis was also performed, describing the magnitude of error introduced by variability in injected dye flow rate, fluorometer variability, error in standards curve preparation, temperature correction, travel time error, and variability in background fluorescence and suspended solids. In general, the majority of error introduced in a typical dye test is related to preparation of standards curves and variation in suspended solids and background fluorescence. A thorough understanding of the theory and potential sources of error in dye testing makes it possible to minimize the key sources of error and perform highly accurate flow rate estimates. The accuracy, portability, and flexibility of the dye testing technique makes it a highly useful method for evaluation and improvement of metering accuracy.

INTRODUCTION

As part of a system-wide evaluation of the accuracy of large meters in the Greater Detroit Regional Sewer System (GDRSS), a rigorous dye dilution testing technique was developed and tested under a detailed laboratory investigation and field implementation procedure. This paper presents highlights of the laboratory study and field work, and concludes with some general guidelines for high-quality dye testing and meter evaluation.

THEORY

A dye dilution test is performed by adding dye to the sewage flow at a constant rate, allowing the dye to mix completely with the sewage flow, and measuring the diluted dye concentration at a downstream location. A mass balance on all fluorescing materials in the system can then be used to estimate the sewage flow based on the degree of dilution observed at the downstream sampling point. Such a mass balance is given by:

$$Q_o C_B + Q_i C_i = (Q_o + Q_i) C_o \quad (1)$$

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where:
Q_i = Injected flow rate
C_i = Injected concentration
C_o = Concentration in mixed (output) flow
C_B = Background concentration
Q_o = Output flow rate to be measured

Expression (1) can be rearranged as:

$$Q_o = \frac{Q_i C_o - Q_i C_i}{C_B - C_o} \tag{2}$$

C_o can be assumed to be very small relative to C_i, so that:

$$Q_o = \frac{Q_i C_i}{C_o - C_B} \tag{3}$$

The analysis technique used in this study eliminates the effect of background fluorescence by using standards prepared from sewage samples. In such a case, a mass balance can be performed on rhodamine dye only, removing C_B from the above development. In this case,

$$Q_o = \frac{Q_i C_i}{C_o} \tag{4a}$$

or

$$Q_o = Q_i D \tag{4b}$$

where D is the measured dilution of injected dye, defined as $D = C_i / C_o$.

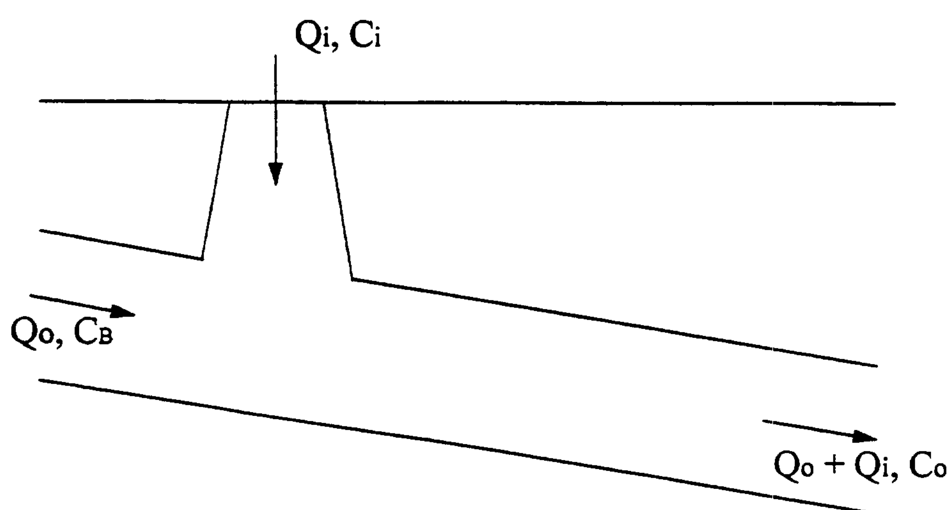

Figure 1. Dye test schematic

LABORATORY INVESTIGATION

Prior to implementing rhodamine dye testing in the field, a laboratory investigation was performed to refine the analytical technique used for measuring dye concentrations, quantify the expected sources of error, and develop a standard testing protocol. Issues explored in the laboratory investigation included:

- variability in the measurement of fluorescence
- variability in dilution preparation and standards curve preparation
- bias or variability due to temperature correction
- variability due to suspended solids fluctuation
- variability or bias due to changes in background fluorescence
- potential effects of poor mixing or non-conservative dye
- consistency of dye injection

While each one of these issues can have a great influence on dye testing performance, space considerations will limit us to a subset of the list given above. This paper will focus on the error involved in standards curve preparation, the importance of temperature correction, and the potential influence of suspended solids and background fluorescence on flow rate predictions. For all investigations reported here, a Turner Designs model 10-AU fluorometer was used for analysis of rhodamine WT concentrations.

Standards Curve Preparation

As noted above in the development of the dye testing equations, the rhodamine dye analytical technique employed in this study involves preparation of standards curves from site- and time-specific sewage samples in order to account for background fluorescence and possible effects of suspended solids. Standards curves are prepared by performing serial dilutions of dye to known concentrations and developing plots of known concentrations vs. measured fluorescence.

A laboratory study was conducted to identify the optimal range over which concentration measurements can be made using the rhodamine WT fluorescence technique. Standards were prepared for several concentration ranges in order to identify the point at which concentration and fluorescence no longer exhibit a linear relationship. Figure 2 shows plots of the standards curves for concentration ranges in the: (a) 0-200 ppb range, (b) 0-500 ppb range, and (c) 0-1000 ppb (1 ppm) range. The fluorometer was respanned for each of the concentration ranges explored. The lower of the three ranges exhibits high linearity, as is claimed in the manufacturer's specifications for the Turner model 10-AU for analysis of rhodamine WT. Extending to the 500 ppb range results in a departure from linearity at higher rhodamine concentrations. The observed nonlinearity is most clearly demonstrated in the 0-1000 ppb standards curve. Even a relatively small deviation from the best fit line as shown in 2b will result in a large increase in the error associated with concentration prediction. For this reason, 200 ppb was identified as a reasonable upper limit for precise concentration measurements.

Standards curves prepared at very low concentrations (0-2, 0-0.2 ppb) in distilled water also showed high linearity, with some increase in scatter at the lowest (<0.1 ppb) ranges. However, a more restrictive low-end constraint in sewer flow rate measurement applications is the presence of background fluorescence, which can obscure low rhodamine concentrations. Measured background fluorescence in samples of sewage collected throughout the GDRSS has generally been in the range of 0.2 to 1.0 (expressed as ppb of rhodamine WT). A factor of 20 times this range gives an effective lower limit of approximately 20 ppb for measurement of rhodamine concentrations. As long as measured fluorescences are significantly greater than background levels, background fluorescence variability will have little impact on measured concentrations.

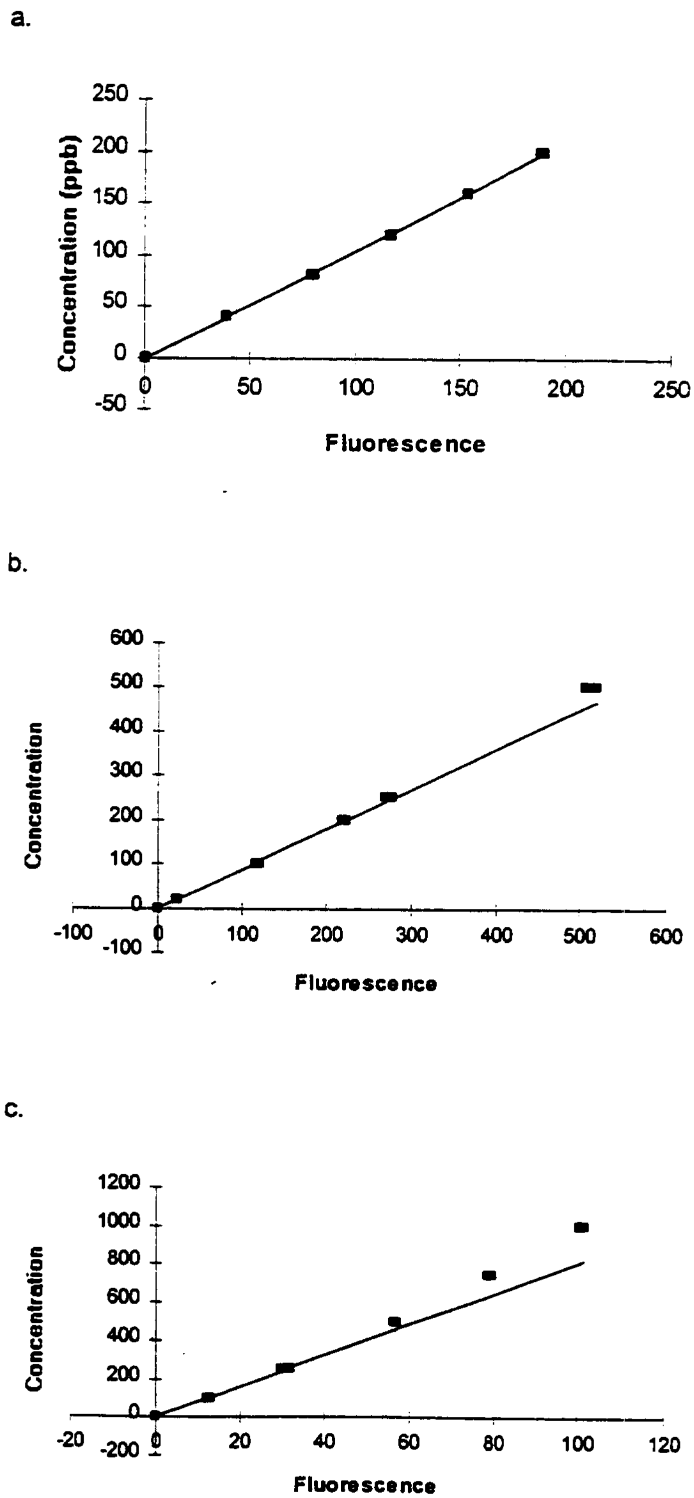

Figure 2: Standards curves for (a) C=0-200 ppb, (b) C=0-500 ppb, (c) C=0-1000 ppb

Reduction of data by regression of a standards data introduces error in the estimation of concentration, due to errors in fluorometric analysis and dilution preparation. The amount of error associated with data scatter can be quantified using the standard error of the estimate produced by the regression. For a regression of the form:

$$y = mx + b \tag{5}$$

the standard error of the estimate is related to the standard error of the regression by:

$$s_{y^*} = s\sqrt{\frac{1}{n} + \frac{n(x^* - \bar{x})^2}{n\sum x_i^2 - (\sum x_i)^2}} \tag{6}$$

where s is the standard error, n is the number of points used in the regression, x^* is the x value at which the estimate of y (y^*) is made, and $\bar{x}$ is the mean value of x over the range of the regression. A 95% confidence interval on the estimate of y is used to estimate the dilution error contribution due to standards curve preparation, and is given by:

$$S(D)_{stds}/D = (t_{0.25,n-2} \cdot s_{y^*})/y^* \tag{7}$$

where t is the t-distribution tabulated in most statistics textbooks.

Error estimates based on (6) and (7) above for a standards curve prepared from wastewater obtained from the Detroit collection system are presented in Figure 3. The accuracy of the estimate is a function of the location on the curve, with the tightest bound on accuracy typically between 60% and 80% of the range of fitted data. Other similar standards curves prepared for the 0-100 ppb range have generally shown estimation errors on the order of 0.5 - 2.0% for the upper 50% of the curve. Based on these results, standards curves prepared for analysis of dye test data are set up so that the majority of collected data falls in the region of minimal estimation error.

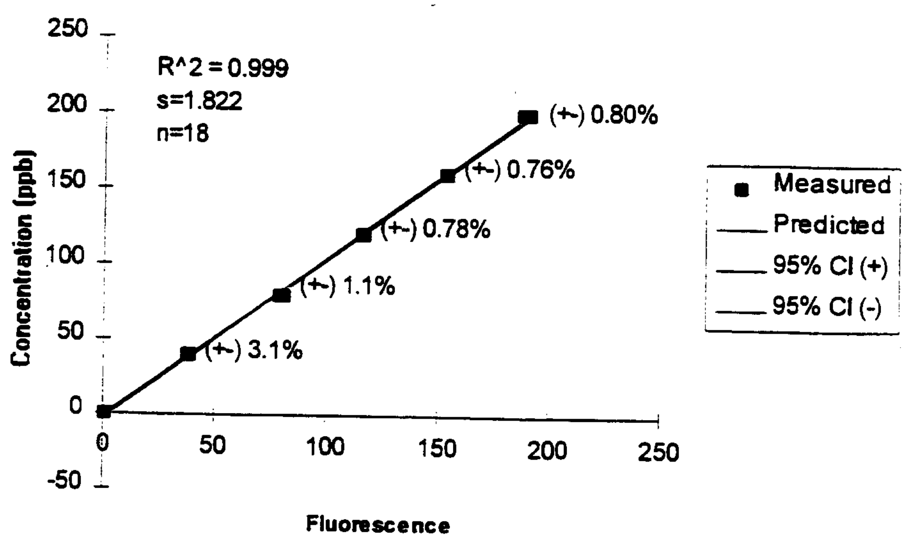

Figure 3: Standards curve with 95% CI on estimate of concentration

Temperature Compensation

It is known that measured fluorescence varies with temperature according to an exponential function of the form:

$$F_r = F_s e^{k(T_s - T_r)} \tag{8}$$

where T_r is the reference temperature, T_s is the sample temperature, F_s is the observed fluorescence of the sample, F_r is the fluorescence, adjusted to the reference temperature, and *k* is the dye batch specific temperature coefficient. Plotting fluorescence vs. temperature data on a semi-log plot (ln(*F*) vs. *T*) should give a straight line with slope equal to -*k*. Linear regression of temperature/fluorescence data is used to estimate the magnitude and 95% confidence interval of the temperature coefficient for each batch (30-gallon drum) of the Cole-Parmer line of rhodamine WT. Data is obtained by continuously pumping a standard solution through the flow-through cell of the fluorometer, and either chilling or warming the reservoir containing the standard. In order to examine the utility of the relationship over the range of dye concentrations expected, standards of 50 ppb and 10 ppb are used. Sample results of such a linear regression is presented in Figure 4. Repeat trials of temperature correction coefficient calculations show highly consistent results within each batch of dye. However, the coefficients can vary by as much as 10% from batch to batch, potentially introducing a major source of error in dye test flow rate estimates if batch-specific values are not determined and used.

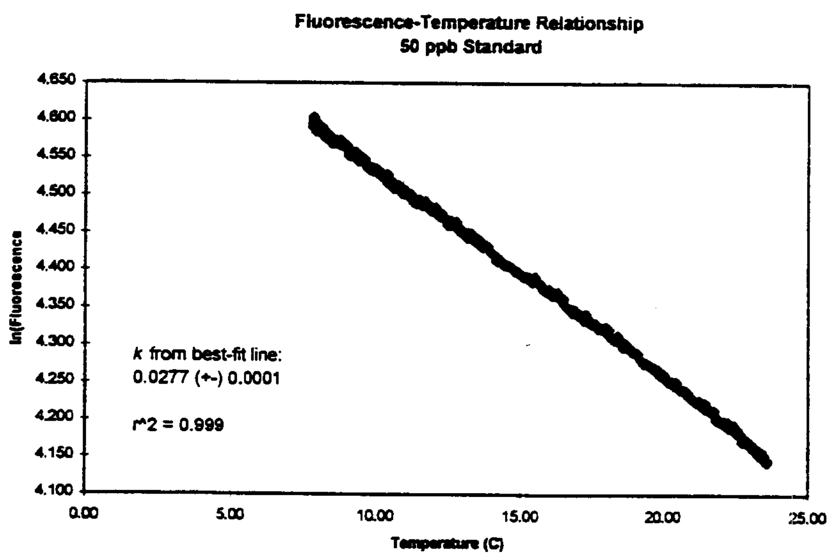

Figure 4: Regression of temperature-fluorescence data for calculation of temperature coefficient

Suspended Solids

The presence of suspended solids in the sewage stream attenuates the amount of fluorescence exhibited by a sample, due to absorbance of the light used to analyze for dye concentration. The fluorometric method used to estimate the concentrations described above implicitly corrects for the presence of suspended solids through the use of sewage to prepare the standards curve dilutions. However, fluctuation in the degree of turbidity can contribute to uncertainty in the measured dye concentrations. Numerous field tests have indicated that the quantity of suspended solids in the sewage stream can fluctuate significantly over the course of a test. Since these fluctuations can occur rapidly, a method is needed to continuously screen for suspended solids changes.

In order to quantify the degree of interference caused by different amounts of suspended solids, a spectrophotometric method was developed. The fluorometric analysis technique used to analyze for rhodamine WT involves bombarding a sample with light at a wavelength of 550 nm, and measuring the emittance of light at the fluorescent wavelength of rhodamine WT of 580 nm. Accordingly, a spectrophotometer was used to measure light transmittance at the two wavelengths of interest in a set of standards prepared at different rhodamine concentrations and with sewage samples from different locations.

Figure 5 shows a fluorescence/absorbance relationship for a standard prepared with sewage obtained from a 36" sewer located in the Clinton-Oakland County Sewerage District. Standards were prepared at concentrations of 20 and 100 ppb rhodamine WT. Fluorescence and absorbance (550 nm) were measured for the standards under well-mixed (high suspended solids) conditions, and after successive amounts of suspended solids had been removed by settling and centrifugation methods. Fluorescence values were then normalized by dividing by the predicted fluorescence in the middle of the range of measured absorbances (Abs = 0.35) in order to make results for the 20 and 100 ppb standards directly comparable.

The results are plotted vs. relative absorbance (measured absorbance minus the reference absorbance of 0.35). As expected, removal of suspended solids has the effect of decreasing light absorbance and correspondingly increasing the measured value of fluorescence. The line fit appears to be equally appropriate for the 100 ppb standard data (triangles) and the 20 ppb data (squares), indicating that this type of relationship is relatively insensitive to the measured concentration.

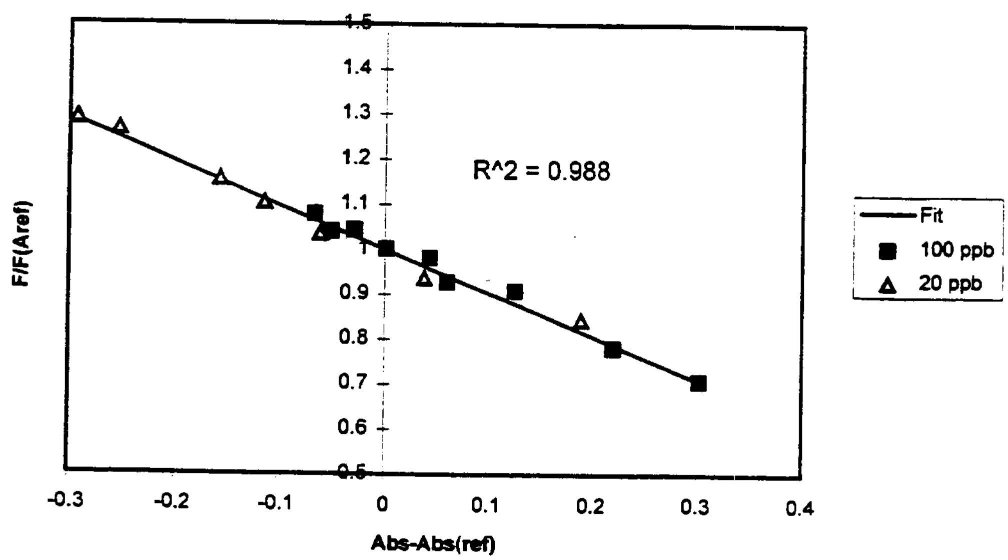

Figure 5: Fluorescence/absorbance relationship for sewage obtained at W. Utica and Dequindre

Initial attempts to use a relationship of the form shown in Figure 5 to correct measured fluorescence values were unsuccessful, as such relationships were found to be highly site- and time-specific. In order to account for the potential influence of light absorbance, the field testing protocol includes collecting upstream (blank) wastewater samples on a fifteen-minute interval, and preparing standards curves from them for time points throughout each test. While absorbance monitoring is not used as a corrective measure, the method is crucial for screening for periods of excessively high absorbance or for rapid changes in absorbance that cannot be accounted for with 15-minute interval standards curves. After performing approximately 100 dye tests, our experience has shown that sudden variation in absorbance is the rule rather than the exception, and screening for absorbance changes is a necessity for estimating both flow rate and the error bound associated with estimated rates. Sample test fluorescence and absorbance traces are shown in Figure 6, showing a clear relationship between measured absorbance and the Rhodamine analytical technique.

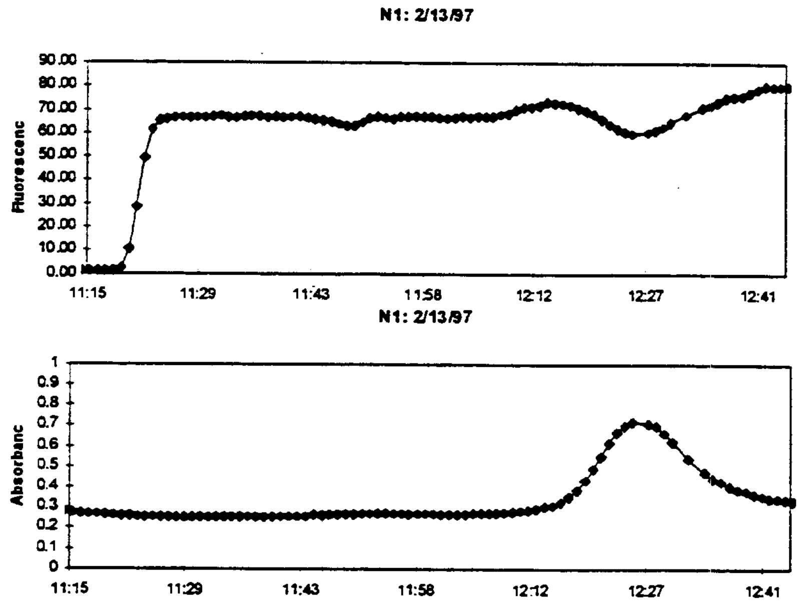

Figure 6: Sample test fluorescence and absorbance traces

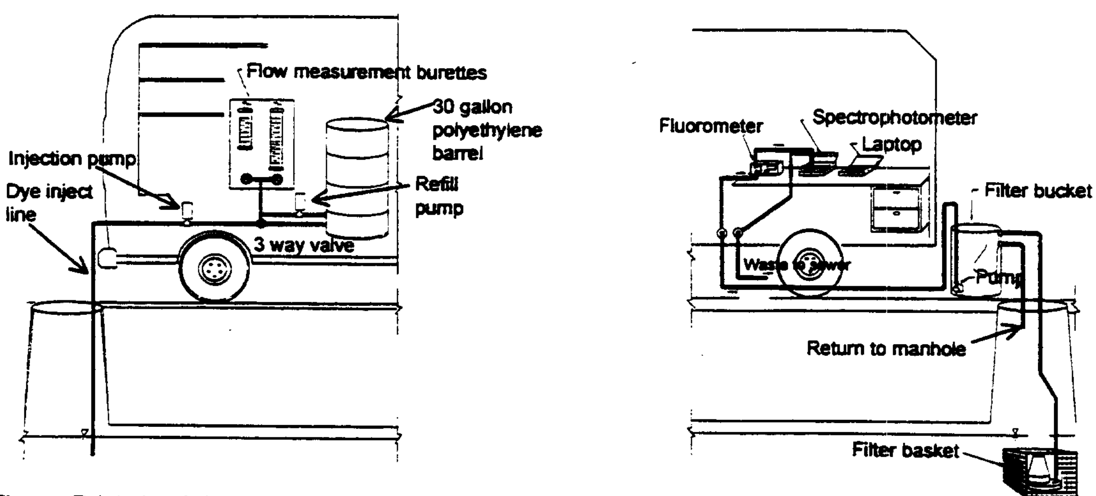

Figure 7 (a) dye inject van; (b) sampling trailer

FIELD IMPLEMENTATION

The dye testing method was implemented in the field by constructing a van-based dye injection system and a trailer used for sample collection and data analysis. Schematics of the van and trailer setups are shown in Figure 7a and b. A fluid metering pump is used to deliver dye into the sewer at a constant rate

(7a), with periodic flow rate checks made by timing the duration required for drawdown of a 250 mL or 500 mL burette. Measurement of the dilution of the dye at the downstream sampling location is performed in the sampling trailer (7b), which utilizes a system of submersible pumps to deliver a sample stream to a fluorometer and spectrophotometer in series. Both the fluorometer and spectrophotometer are linked to a laptop PC for continuous collection and plotting of fluorescence, absorbance and temperature data.

RESULTS

In order to check for bias in the testing method, dye testing results were compared with high quality magmeter flow estimates and with drawdown testing performed at the Greenfield pump station, located in Dearborn, Michigan. Testing was performed by abruptly closing the wet well influent gate and recording well depths while dye testing and magmeter recording was underway downstream. Flows were calculated by determining the cross-sectional area of the wet well at the depths recorded during the test, and multiplying by the change in depth for each time interval recorded. Results of the drawdown testing are presented in Figure 8, showing a consistent drawdown rate over the five minute run of the test and an average flow over the test of 21.3 cfs. The dye test/meter comparison is given in Figure 9, showing agreement between dye test and meter values at the three comparison points (standards curve prep times). An overall summary is found in Table 1, indicating a good three-way comparison between the dye test, drawdown and meter flow rate results (dye test/meter multiplication factor = 0.99 ± 0.05, meter/drawdown comparison 20.4/21.3 cfs at 12:40). These results are highly consistent with similar testing performed in March of 1997.

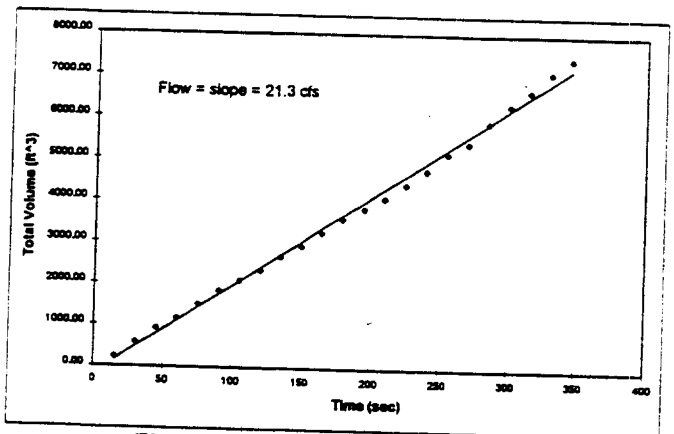

Figure 8: Drawdown testing results

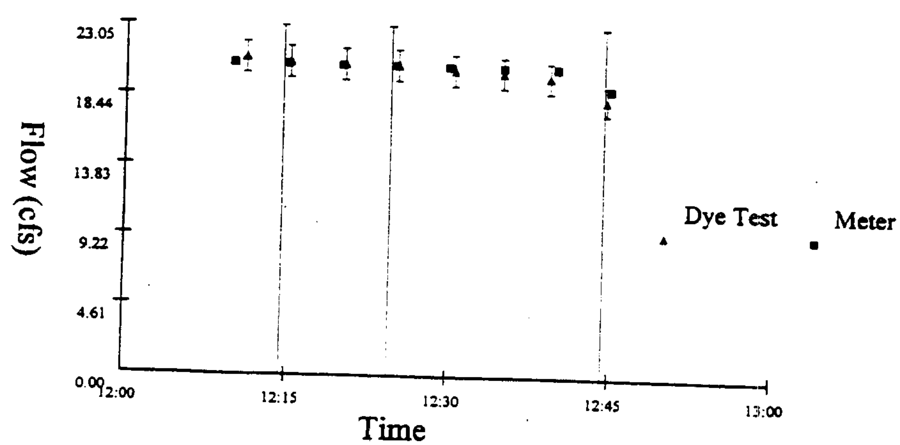

Figure 9: Dye test/meter comparison

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Table 1: Dye test/ magmeter/ drawdown test comparison

Time	Flow (cfs) Dye Test	Meter	Drawdown Test	Mult. Factor	Dye Test Uncertainty (RSS)
12:15	20.7	20.5		1.01	5.0%
12:25	20.5	20.5		1.00	5.1%
12:40		20.4	21.3		
12:45	18.3	19.0		0.96	5.1%
			average:	0.99 ± 0.05	5.0%

*Multiplication factor =dye test results/metered values

DISCUSSION AND CONCLUSIONS

While space considerations limit us to a brief discussion of our development of a rigorous dye testing method, the complete error analysis performed to support this study identified a number of key requirements for accurate and reliable dye testing. While not detailed in this paper, these requirements are listed below:

- Continuous monitoring of dye injection rate
- Verification of dye consistency throughout
- Accounting for time-of-travel
- High quality standards curve preparation from representative sewage samples
- Frequent standards curve preparation
- Continuous monitoring of suspended solids
- Comprehensive error analysis

Peformance of a comprehensive error analysis includes accounting for the contribution of each one of these factors to the overall uncertainty of the flow rate estimate. In general, the majority of error introduced in a typical dye test is related to preparation of standards curves and variation in suspended solids and background fluorescence. In general, a thorough understanding of the theory and potential sources of error in dye testing makes it possible to minimize the key sources of error and perform highly accurate flow rate estimates.

The testing methods described in this paper have been used to perform well over 100 dye tests at metering sites throughout the greater Detroit area. The method has been used to measure flows from 3 to 350 cfs, and has been shown to give highly accurate and consistent results throughout the range of measured flow rates. As part of a system-wide evaluation of meter accuracy in the GDRSS, dye testing has been invaluable in identifying problems with existing meter installations and building confidence in the operation of many of the meters in the system. Dye testing has also been a valuable tool for verifying the accuracy of new meters and debugging problems with installations.

Based on our experience with a wide range of metering technologies, including point- and transit-time ultrasonic meters, magmeters, and flumes and weirs, our general observation has been that problems with meters tend to be related to specific installations, rather than to any particular technology or manufacturer. Given this observation, it is our recommendation that calibration or verification of meter accuracy should be performed for virtually any installation, regardless of manufacturer's claims to the contrary. Our experience has shown dye testing to be a valuable tool for achieving this goal.

IS COMPREHENSIVE REHABILITATION FOR I/I REMOVAL COST EFFECTIVE IN HOUSTON?

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ABSTRACT

The City of Houston was under mandates from the U.S. Environmental Protection Agency (EPA) and the Texas Natural Resource Conservation Commission (TNRCC) to control wet-weather overflows caused by excessive infiltration/inflow (I/I) during rainfall events by December 31, 1997. The City of Houston complied with these regulatory orders by completing the largest Sanitary Sewer Overflow (SSO) correction program in the country, notwithstanding extremely tight schedule constraints and a massive $1.17 billion capital improvement program. The Wastewater Program (Program) was created in 1992 to manage the work toward mandated compliance.

One of the alternatives analyzed for achieving compliance with the administrative orders was sewer system rehabilitation to reduce I/I. The analysis made the assumption that comprehensive rehabilitation is required to achieve significant I/I reduction. Rehabilitation that addresses all components of the system (mainlines, laterals, and services) is termed "comprehensive rehabilitation". The analysis determined that this type of rehabilitation was not cost effective on a system wide basis for Houston. It is speculated that this is due in part to Houston's unique climatology and collection system characteristics. It should be noted that this analysis studied only comprehensive rehabilitation. Other kinds of rehabilitation may prove to be cost-effective even in Houston.

A rehabilitation demonstration project was undertaken to determine the costs and effectiveness of two levels of rehabilitation in reducing rainfall dependent I/I (RDI/I). The extent of rehabilitation under both levels was less than that of comprehensive rehabilitation. Both approaches were less effective at reducing RDI/I than the method for comprehensive rehabilitation assumed in the Houston analyses. In a subsequent analysis in one of the demonstration basins, the incremental cost to complete the rehabilitation effort on private property (i.e. expand the rehabilitation effort to comprehensive) was shown to be more expensive than providing relief sewers in that basin to alleviate potential overflow conditions.

KEYWORDS

RDI/I, rehabilitation, cost effective, comprehensive rehabilitation

INTRODUCTION

The analysis of the cost-effectiveness of sewer system rehabilitation used in the City of Houston Cost-Effectiveness Analysis (CEA) has been based on the assumption that significant reductions in RDI/I can only be achieved in a given area of the system when every sewer line up to 30.5 cm (12 inches) in diameter is rehabilitated. This includes all main lines in the public right-of-way and in easements, and all laterals and private services. The rationale behind this assumption is that water migrates. If only the detected leak defects in a sewer reach are fixed, the water will migrate to other nearby undetected defects or the next sewer reach, which may not have been previously leaking. In 1980, EPA analyzed 18 municipal sewer systems that had completed EPA Step 3 Construction Grant projects on sewer line rehabilitation (Conklin, 1980). They found that realized RDI/I reduction fell short of predicted reduction. One of the contributors was a migration of water from repaired joints to joints that had not been repaired. Since then, rehabilitation projects throughout the country have reported wide ranges in RDI/I reductions,

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demonstrating the complexity and difficulty in predicting the I/I reduction benefits from sewer system rehabilitation.

For the Houston CEA, assumptions were made on the effectiveness or efficiency of removal of RDI/I by comprehensive rehabilitation. For other methods of rehabilitation which did not address all mainlines, laterals and private services, it was assumed that the effectiveness of RDI/I removal could not be conclusively established theoretically but only through demonstration projects.

METHODOLOGY

Houston's large sanitary sewer collection system encompasses 9,656,000 km (6,000 miles) of mainline pipe in 51 wastewater treatment plant service areas. It was divided into three groups, called Rounds in the administrative orders, for analysis purposes. The Round 1 service areas encompass approximately 26 percent of the City by area, and the Round 2 service areas encompass approximately 53 percent of the City. Due to schedule considerations, the Round 1 CEA had to be completed in the first 90 days of the Program. This necessitated that simplifying assumptions be made to accelerate the analysis.

Round 1 Analysis

The comprehensive rehabilitation assumption was applied to each hydrograph basin, the smallest unit of flow input to the Program's SWMM EXTRAN model. A hydrograph basin typically consists of several upstream temporary flow monitor subbasins, each comprised of 1,500 to 6,000 m (5,000 to 20,000 linear feet) of main line sewers. Therefore, a typical hydrograph basin might include 6,000 to 30,000 m (20,000 to 100,000 linear feet) of main line sewers.

Comprehensive rehabilitation was assumed to achieve a 70 percent reduction in RDI/I (both volume and peak) within the area rehabilitated. It was assumed that roughly 80 percent of the RDI/I was contributed by the worst 50 percent of the basin. Therefore, comprehensive rehabilitation within the subbasins comprising the worst 50 percent of the basin would reduce the total basin RDI/I by about 50 percent (70 percent reduction of 80 percent of the RDI/I equals 56 percent reduction, which was rounded down to 50 percent).

The total potential cost savings in relief, treatment, and wet weather facilities resulting from comprehensive rehabilitation was estimated for each service area and allocated to each hydrograph basin in proportion to its RDI/I contribution. The total service area overflow correction cost (sum of relief, treatment, and wet weather facilities plus comprehensive rehabilitation) was plotted as a function of increasing RDI/I removed, and the lowest total cost was determined from this curve. The curve was developed by making broad assumptions about the relationship between flow reduction in the upstream basins and the resultant sizes of downstream relief projects. For each service area, model runs were made for the 0 percent and 100 percent rehabilitation scenarios (equivalent to 0 and 50 percent RDI/I reduction, respectively) plus two intermediate points, and the curve was interpolated between these points. The resultant cost-effectiveness curve for the FWSD No. 23 Service Area in Houston is shown in Figure 1.

Based on these assumptions for the Round 1 service areas, it was determined that comprehensive rehabilitation was not cost-effective. Rather, the most cost-effective overflow control alternative was found to be a combination of relief and treatment, and wet weather facilities in some service areas.

Round 2 Analysis

The comprehensive rehabilitation assumptions were modified for the Round 2 service areas for several reasons. The schedule allowed more time to do a more detailed analysis, and there was genuine interest in giving comprehensive rehabilitation every chance to succeed. The Round 1 rehabilitation assumptions were modified for the Round 2 analysis, as follows:

The unit of analysis for comprehensive rehabilitation was the smaller subbasin rather than the larger hydrograph basin.

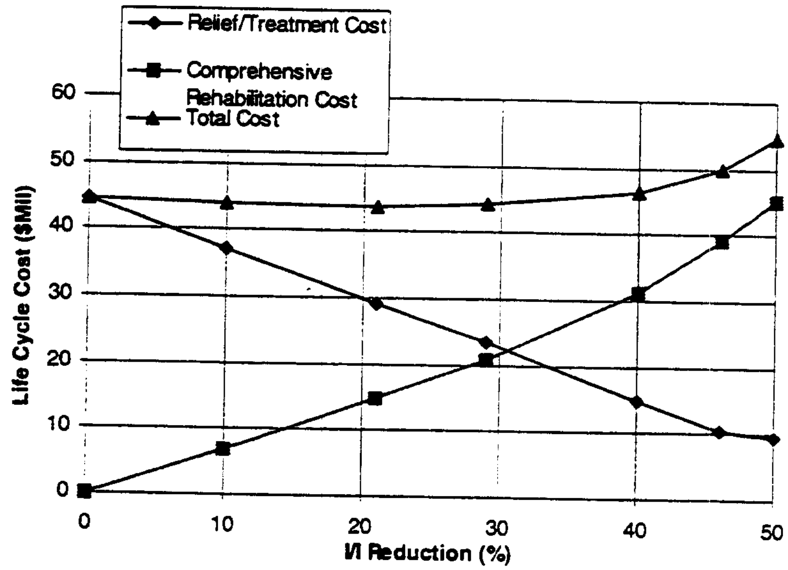

Figure 1. Typical Cost-Effectiveness Analysis Curve

It was reasoned that if every main line, lateral, and service within a subbasin were rehabilitated, then the resulting RDI/I rate should reasonably be similar to that of a newly constructed sewer system, regardless of the existing RDI/I rate. The 2-year design storm peak RDI/I rate used in the CEA for areas of future development is 23.4 m^3/ha/day (2,500 gpad). The RDI/I rate, or "cap", for a newly rehabilitated subbasin was set at twice this amount, or 46.8 m^3/ha/day (5,000 gpad). This cap was assumed to be the same whether the existing RDI/I rate for a subbasin was relatively low (e.g., 93.5 m^3/ha/day; 10,000 gpad) or very high (e.g., 1,870 m^3/ha/day; 200,000 gpad). This more aggressive approach in RDI/I reduction was intended to target the leakiest basins in the City. Figure 2 shows the range of projected design flow rates for one of the Round 2 service areas. One hundred percent rehabilitation in a subbasin was assumed to be required to achieve an RDI/I rate of 46.8 m^3/ha/day (5,000 gpad).

In the Round 1 cost-effectiveness analyses, the specific subbasins that formed the 50 percent of the basin which was rehabilitated were not identified, nor were the specific downstream projects affected by comprehensive rehabilitation in each basin identified. The Round 1 analysis simply assumed that downstream projects in general would diminish in direct proportion to the reduction in flow attributed to comprehensive rehabilitation of the upstream subbasins. For the Round 2 analysis, a direct relationship was established between the reduction in RDI/I due to the rehabilitation in a particular subbasin or group of subbasins and the resultant change in the required downstream projects. The cost savings realized through the elimination or downsizing of a downstream project was distributed to each upstream subbasin that contributed to the savings. Distribution was on the basis of peak flow reduction in the case of relief and treatment facilities and flow volume in the case of wet weather facilities.

CE ratios. The cost effectiveness of comprehensive rehabilitation was determined by comparison of the cost to rehabilitate a subbasin to the cost saved by the reduction of downstream projects. A cost-effectiveness (CE) ratio was calculated for each subbasin. The CE ratio is defined as the ratio between the cost savings realized in the downstream project reductions due directly to the comprehensive rehabilitation of an upstream subbasin and the cost to rehabilitate the subbasin. Needed structural rehabilitation in a subbasin was also considered in the analysis. This was accomplished by reducing the estimated cost for comprehensive rehabilitation by the cost of either incurred or planned structural rehabilitation. For subbasins in which structural rehabilitation plans have not been developed, structural rehabilitation costs were estimated based on the structural rehabilitation costs in adjacent subbasins. This adjustment was made to ensure that deterioration of the existing pipe system was accounted for in the analysis.

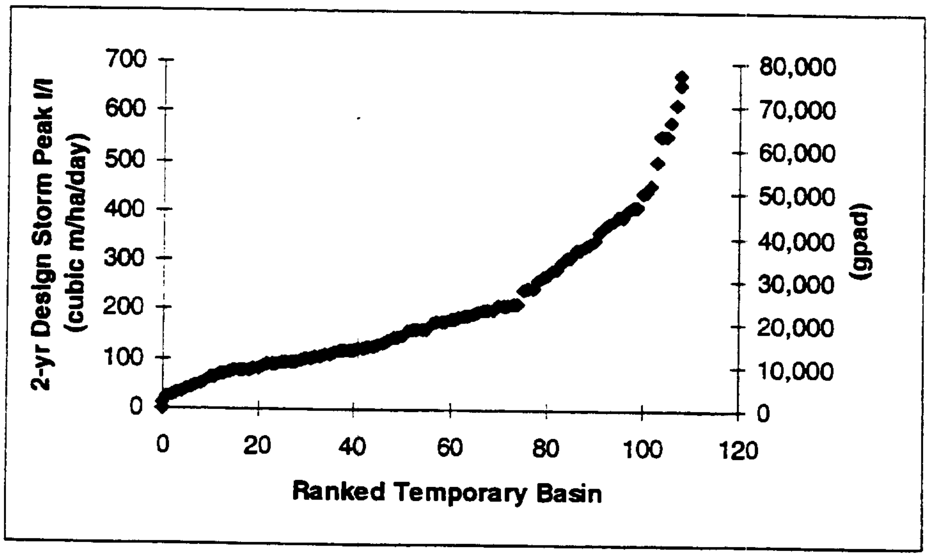

Figure 2. Variation of Design RDI/I Rate for Typical Service Area

Subbasins with CE ratios greater than 1.0 were assumed to be cost effective to rehabilitate. Preliminary CE ratios were determined first by an initial model run assuming comprehensive rehabilitation and a resulting reduction in existing RDI/I flow for all subbasins in the service area. Then, a second run was made in which existing RDI/I flows were reduced only for those subbasins with initial CE ratios greater than 1.0. In this run, fewer projects were eliminated and project reductions were smaller than in the initial run because the overall flow reduction was less. The revised CE ratios calculated based on the second run were generally smaller than the initial values, and fewer CE ratios were found to be greater than 1.0.

The effectiveness of comprehensive rehabilitation in reducing flows and eliminating or reducing downstream projects is illustrated in the computation of the CE ratios for the subbasins in a service area. The Northside Phase II and Almeda Sims service areas were the only Round 2 service areas that had any subbasins with initial CE ratios greater than 1.0. (A few subbasins in other service areas had initial CE ratios between 1.0 and 1.1, but these were considered too marginal for further consideration.) When subsequent computer runs were completed in which subbasin flow reductions were assumed only in those subbasins with initial CE ratios greater than 1.0, the overall flows in the system increased. Fewer downstream projects were eliminated or reduced causing a reduction in the cost benefit of the upstream rehabilitation. This was generally sufficient to lower the CE ratios below 1.0.

Results. Of the 650 Round 2 subbasins analyzed, only two had a final CE ratio greater than 1.0. Both subbasins, however, are on the list of subbasins targeted for review and flow re-monitoring because their high flow projections are not supported by the field investigations summarized in the Physical Inspection Reports. Flow re-monitoring has the potential to both reduce projected design flows and eliminate or reduce the need for downstream projects, which would likely reduce the CE ratios to below 1.0.

In addition, the final CE ratios are based only on life cycle capital costs. There are other costs associated with implementation of a private services rehabilitation program including such things as inspection, testing, and legal fees. If the City were responsible for all or a portion of these additional costs, the rehabilitation alternative becomes more expensive and less attractive; the CE ratios decrease. For these reasons, it was concluded that comprehensive rehabilitation was not cost-effective in the Round 2 service areas. Comprehensive rehabilitation analysis was not undertaken in the remaining service areas. It was reasoned that Rounds 1 and 2 encompass approximately 80 percent of the City, and the chance that comprehensive rehabilitation would be found cost effective elsewhere in Houston was too small to expend the effort in analysis.

There are several factors which are believed to contribute these results. Houston/Gulf Coast climatology is characterized by two types of storm events. Frontal storm events usually are of longer duration and have lower intensities. These storms do not tend to be the ones that cause the overflow problems. Summer thunder storms with short durations, high intensities cause flows with wet-weather peaks typically 20 times the dry weather flow. These storms are the ones likely to cause overflow problems. However, while these storms cause high peak flows, they are low volume events. The isolated facilities in the system, trunk sewers and lift stations, that do not have sufficient capacity to convey the peak flow cause the flow to back up in the system and overflow. When these bottle necks are relieved, the overflows are eliminated. It is generally much cheaper to relieve these bottle necks than to rehabilitate all of the pipes in an area to keep the flow out in the first place.

Cedar Bayou Service Area

Whereas the Round 2 comprehensive rehabilitation analysis was more detailed and aggressive than the Round 1 analysis, it also made some simplifying assumptions with regards to the number of private service in a service area, the manner and magnitude of future growth, and the cost of relief facilities. An analysis was prepared for the Cedar Bayou Service Area in which these quantities were refined further.

Based on the CEA for the Cedar Bayou Service Area, a relief, transport and treat alternative was identified as the cost-effective solution. The recommended facilities were progressed through preliminary and final design resulting in the following estimated capital costs shown in Table 1.

Table 1
Total Overflow Control Costs Without Rehabilitation
Cedar Bayou Service Area

WWTP LS and Stormwater Clarifier	$2,971,000
WCID No. 73 LS, 40.6 cm (16 in) FM, 76.2 cm (30 in) Sewer	$5,359,000
Sunny Glen LS and 30.5 cm (12 in) FM	$1,526,000
Glengyle LS and Relief	$347,000
TOTAL	$10,203,000

It was decided to revisit the rehabilitation analysis beginning with the design flows. There are a total of 675 served and 377 unserved dwelling units in Cedar Bayou for an estimated population of 3,156 (1,052 units X 3.0 people/unit). A population projection was prepared based on current census tract growth rates tempered by the availability of infrastructure improvements to encourage growth. The projected population for the year 2030 (the planning horizon) is 4,960. Future flow estimates were based on this number.

assuming reductions of RDI/I as high as 95 percent for comprehensive rehabilitation. Even in these cases, comprehensive rehabilitation was not cost effective. The conclusion is that comprehensive rehabilitation is not cost effective in Houston. It is cheaper to relieve Houston's collection system bottle necks for the short duration, high intensity thunder storms of the Gulf Coast region.

In addition to comprehensive rehabilitation, a rehabilitation demonstration construction project with pre- and post-rehabilitation flow monitoring studied two other methods of rehabilitation less extensive than comprehensive rehabilitation. These two methods were found to be effective at reducing RDI/I, but were less effective at reducing RDI/I than the method for comprehensive rehabilitation assumed in the Houston analyses.

It should be noted, however, that many types of rehabilitation with varying levels of rehabilitation were not tested and could prove to be cost effective. In addition, the methods of rehabilitation tested could prove to be cost effective for more limited, localized problems in other portions of the City's system. Finally, soil characteristics and climatology vary from region to region as well as sewer system conditions and available system capacity, and the conclusions found for Houston may not be applicable in other parts of the country.

ACKNOWLEDGMENTS

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TEST BASINS FOR I/I REDUCTION AND SSO ELIMINATION

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ABSTRACT

This paper discusses a method of evaluating and optimizing effectiveness of sewer rehabilitation. It proposes standard methods for reporting and evaluating sewer rehabilitation projects that will allow readers to understand the project and compare it to others.

KEY WORDS

I/I Reduction, Sewer Rehabilitation, Effectiveness, SSO Elimination

INTRODUCTION

Thousands of communities and municipalities, nationwide have rehabilitated portions of their collection systems, yet very few know whether or not they have been successful. With its current focus on SSO's, EPA expects communities to spend more than $20 billion on sewer rehabilitation in an effort to eliminate SSO's. The big problem is that no one can forecast how effective the rehabilitation will be. EPA doesn't know; the communities don't know and the engineers don't know. That amounts to a $20 billion program whose outcome is extremely uncertain. It might make sense to find out more about the actual effectiveness of rehab before committing the entire county to a $20 billion project.

This paper proposes using small test basins or pilot projects in each community to find out what really works before committing the community to a large-scale sewer rehabilitation program. On a small basin, a community and its engineer can afford to experiment without breaking the bank. Try to eliminate direct connections and see how much I/I that removes. If that doesn't remove enough I/I, try rehabilitating the sewer mains and see how much more I/I that eliminates. And if that doesn't work out very well, try rehabilitating the building laterals. If none of the rehab strategies work, then the municipality may need to abandon rehab altogether and just build bigger sewers, bigger plants and perhaps off-line storage for wet weather flows. In the end each community should be able to settle on a strategy that works the best for its own sewer system.

The large majority of North American engineers and regulators, with a few notable exceptions, take a pessimistic view of sewer rehabilitation. Very few believe that rehab can remove any more than 30% or 35% of the I/I from a sewer system. In Ohio, its even institutionalized; Ohio EPA will not issue loan money to communities that forecast I/I reductions that exceed 35%. They don't believe a community can achieve better than 35% reduction. So how successful can rehabilitation really be?

Extensive research through published literature and engineering reports has yielded some interesting information about sewer system rehabilitation:

1. I/I reduction information is available from at least 91 sewersheds worldwide
2. The average reported reduction is 49% of peak I/I rate
3. The standard deviation is 25%, meaning that about two-thirds of the reported projects fall between 25% reduction and 75% reduction
4. Twelve projects exceeded 75% reduction

References for most of the sewersheds cited above are included at the end of this paper. Table 1, shown below, shows the I/I reductions as reported in the literature. References are cited in the rightmost column.

Table 1 – Published I/I Reduction Results

City	State	Basin Name	Year	Percent Reduction	Percent Manholes Fixed	Percent Lines Fixed	Percent Laterals Fixed	Reference
Cordova	AK		1992	37%	100%	85%	7%	15
Fayetteville	AR		?	75%	?	?	?	
Camp Robinson	AR		1996	85%	?	51%	?	7
Sydney	Austr.	Drummoyne - SPS 30	1994	75%	?	86%	72%	13
Sydney	Austr.	Pymble	1994	31%	?	39%	0%	13
Sydney	Austr.	Pymble - Station St.	1994	59%	?	100%	0%	13
Sydney	Austr.	Pymble - Church St.	1994	13%	?	100%	0%	13
Sydney	Austr.	Corrimal	1997	35%	?	25%	12%	6
Sydney	Austr.	Corrimal - Louis St.	1994	60%	?	80%	50%	13
Sydney	Austr.	Corrimal - ICC Depot	1994	56%	?	80%	50%	13
Sydney	Austr.	Corrimal - Midgley L.	1994	53%	?	80%	50%	13
Sydney	Austr.	Bexley North	1997	67%	?	50%	48%	6
Sydney	Austr.	Ashcroft	1994	31%	?	10%	7%	13
Sydney	Austr.	Ashcroft - Friesan St.	1994	48%	?	80%	50%	13
Sydney	Austr.	Bexley - McDonald Cr.	1994	50%	?	50%	48%	13
Sydney	Austr.	Manly	1994	45%	?	67%	23%	13
Sydney	Austr.	Lalor Park - MC-01	1994	45%	?	80%	50%	13
Sydney	Austr.	Lalor Park - MC-13	1994	67%	?	80%	50%	13
Sydney	Austr.	Lalor Park - MC-17	1994	26%	?	80%	50%	13
Sydney	Austr.	Dapto - Whole Area	1994	25%	?	15%	33%	13
Sydney	Austr.	Dapto MC-30	1997	75%	?	80%	50%	6
Sydney	Austr.	Dapto MC-02	1994	33%	?	80%	50%	13
Sydney	Austr.	Dapto MC-03	1994	50%	?	80%	50%	13
Sydney	Austr.	Dapto MC-05	1994	60%	?	80%	50%	13
Sydney	Austr.	Dapto MC-20	1994	75%	?	80%	50%	13
Sydney	Austr.	Dapto MC-19	1994	61%	?	80%	50%	13
Sydney	Austr.	Orphan School Creek - N	1997	48%	?	14%	25%	6
Sydney	Austr.	Orphan School Creek - W	1994	42%	?	24%	17%	13
Dunsmuir	CA		1980	0%	?	?	?	21
Stege Sanitary District, CA	CA	Subarea N	1990	86%	100%	100%	100%	17
Tallahassee	FL		?	92%	?	?	?	
Streamwood	IL	Streamwood	1982	63%	65%	1%	10%	22
Wheaton	IL	Arrowhead	1982	64%	62%	0%	16%	22
Broadview	IL		1995	59%	?	?	0%	8
Mattesen	IL		1995	82%	?	?	0%	8
Melrose Park	IL		1995	49%	?	?	0%	8
Elk Grove Village	IL		1987	42%	100%	2%	31%	20
Winnetka	IL		1987	68%	100%	12%	6%	20

Hoffman Estates	IL		1987	32%	100%	7%	14%	20
	IL		1987	61%	100%	15%	3%	20
Lexington Fayette Urban County Government	KY	Highlands P.S.	1992	32%	89%	0%	0%	9
Lexington Fayette Urban County Government	KY	Mint Lane P.S.	1995	66%	84%	0%	0%	9
Lexington Fayette Urban County Government	KY	Hartland #1 P.S.	1995	44%	93%	0%	0%	9
Lexington Fayette Urban County Government	KY	Hartland #2 P.S.	1995	43%	71%	0%	0%	9
Lexington Fayette Urban County Government	KY	Hartland #3 P.S.	1995	38%	92%	0%	0%	9
Lexington Fayette Urban County Government	KY	Armstrong Mill P.S.	1995	12%	86%	0%	0%	9
Lexington Fayette Urban County Government	KY	East Lake P.S.	1995	24%	76%	0%	0%	9
New Buffalo	MI		1980	1%	?	?	?	21
Burlington	NC	Gunn Creek	?	49%	?	?	?	
Charlotte-Mecklenburg Utility Department	NC	CB-14	1997	46%	100%	100%	100%	5
Charlotte-Mecklenburg Utility Department	NC	M-9	1997	57%	100%	100%	100%	5
Charlotte-Mecklenburg Utility Department	NC	CC-6	1997	13%	40%	40%	0%	5
Charlotte-Mecklenburg Utility Department	NC	CC-14	1997	0%	6%	6%	0%	5
Fairport Harbor	OH	FP2	1988	39%	0%	100%	100%	18
Fairport Harbor	OH	FP1	1988	0%	0%	100%	0%	18
North Olmsted	OH		1994	60%		39%	215	12
Toledo	OH	PP-12	1998	49%	0%	0%	19%	2
Unified Sewage Agency of Washington County	OR	Cedar Hills	1993	60%	92%	92%	79%	14
Unified Sewage Agency of Washington County	OR	Forest Grove	?	70%	?	?	?	?
Mt. Holly	PA		1980	23%	?	?	?	21
Amity	PA		1980	24%	?	?	?	21
Coyningham	PA		1980	17%	?	?	?	21
Lower Paxton Township	PA	Subbasin 1	1997	90%	?	?	?	4
Lower Paxton Township	PA	Subbasin 2	1997	56%	?	?	?	4
Lower Paxton Township	PA	Subbasin 3	1997	53%	?	?	?	4
Lower Paxton Township	PA	Subbasin 6	1997	81%	?	?	?	4
Athens	TN		?	63%	?	?	?	
Murphreesboro	TN	Bradyville Road	1987	85%	?	?	?	19
Nashville	TN	Oak Valley	1991	79%	41%	41%	?	16
Nashville	TN	Collier	1994	54%	12%	12%	?	11
Nashville	TN	Hopedale	1994	73%	21%	21%	?	11
Nashville	TN	Kenner	1994	88%	45%	45%	?	11
Nashville	TN	West Linden	1994	45%	93%	93%	?	11
Nashville	TN	Seven Mile IDU45	1997	0%	1%	1%	?	11
Nashville	TN	Lower East Nashville (5)	1997	43%	12%	12%	?	11
Nashville	TN	Sugartree	1997	51%	15%	15%	?	11
Nashville	TN	Paragon Mills (PM1)	1997	86%	21%	21%	?	11

Nashville	TN	Anderson Road (PR3)	1997	40%	22%	22%	?	11
Nashville	TN	Lower East Nashville (6)	1997	19%	25%	25%	?	11
Nashville	TN	Smith Springs (SS3)	1997	41%	33%	33%	?	11
Nashville	TN	Paragon Mills (PM2)	1997	81%	46%	46%	?	11
Crosby	TX	CO-3	1994	60%	100%	0%	0%	10
Houston	TX		?	80%	?	?	?	
Houston	TX	II109	1998	39%	?	?	?	1
Houston	TX	II149	1998	72%	?	?	?	1
Houston	TX	II017	1998	54%	?	?	?	1
Houston	TX	II021	1998	27%	?	?	?	1
Castle Rock	WA		1983	60%	?	100%	12%	21
Centralia	WA		1980	3%	?	?	?	21
Shelton	WA		1980	-6%	?	?	?	21
Sussex	WI		1980	7%	?	?	?	21

REPORTING STANDARDS

The large number of question marks and blanks in Table 1 above suggest the need for consistent reporting standards. If the industry is to learn what works and what doesn't, then authors should report their results more completely. In effect, authors should report enough information to complete Table 1 above.

First the rehabilitated sewer system should be fully inventoried and described. Describe sizes and lengths of mainline sewer as well as pipe materials, joints, type of backfill and type of trenches, (i.e. common trench versus separate trench, see Figure 1). Describe manhole construction and materials including frames and covers. Discuss the condition of the joint between the frames and the top section of manhole. Don't forget building laterals. Report the number of buildings, the sizes and types of pipe used both inside and outside the right-of-way. Discuss ownership of the laterals and describe the location and configuration of cleanouts, if any.

Report the percentage of mainline sewers, the percentage of manholes and the percentage of laterals actually rehabilitated.

To estimate actual I/I reduction, compare rainfall derived I/I (RDII) versus rainfall for many storms both before and after rehabilitation. Report the number of wet weather events used – both before and after. Calculate both the mean percentage of I/I removed and the standard deviation. Finally, report the same statistics for the control basin to adjust for seasonal or antecedent differences between the pre-rehab RDII and the post-rehab RDII.

One reason that most agencies and professionals remain skeptical of rehabilitation is that the information published in Table-1, above, has not been well publicized. Compiling the list has involved researching every reference listed at the end of every manuscript on I/I reduction that the author has ever read. In addition, it has involved questioning engineers, over the last 10 years about measurable I/I reduction projects in which they had been involved. A second reason that many professionals remain skeptical is that thousands of their own

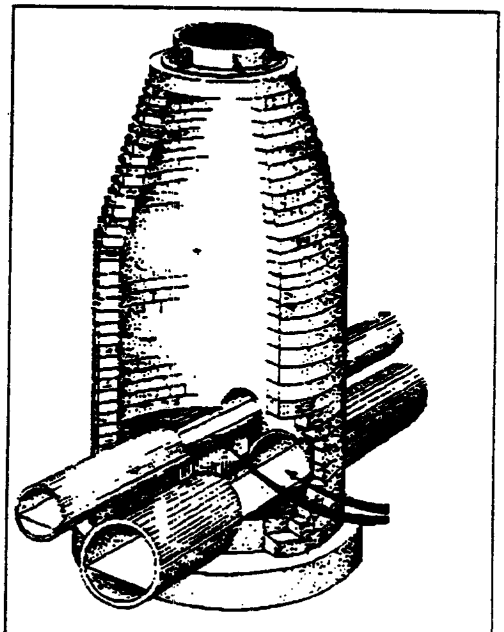

Figure 1 – Common Trench Sewer with Single Manhole

communities have had negative experiences with sewer rehabilitation. That is, many communities have spent lots of money on sewer rehabilitation with no discernible, tangible or measurable results.[24]

Even though a list of 91 projects may seem impressive, it represents less than 1% of all sewer rehabilitation projects ever conducted. Why are successful sewer rehabilitation projects so rare? Why does rehabilitation apparently fail to remove significant portions of I/I so often? How many rehabilitation projects may have actually been successful with no way of knowing?

These are important questions since one of the central strategies in SSO elimination is I/I reduction. To the extent that I/I reduction is successful, all the other strategies become less expensive. For instance, if a community can eliminate 70% of its I/I then it may not have to enlarge any sewers or treatment works saving an immense amount of money. Conversely, if that same community fails to remove any more than 30% of its I/I, then it may need to invest millions more dollars in sewer system enlargement to eliminate SSO's.

After more than a quarter of a century of sewer rehabilitation experience the collection systems community still can not predict, with reasonable confidence, how much I/I a community could expect to eliminate. We don't have enough data and it's our own fault. EPA hasn't demanded it; consultants haven't requested it, and municipalities haven't required it. So were still operating in the dark on a $20 billion question.

METHODOLOGY

One way to capture the needed data is to set up a network of small test basins. If each community contemplating significant sewer rehabilitation would set up a small test basin, say 5,000 to 15,000 linear feet of mainline sewer, and also set up a control basin of similar size, then we could start collecting the needed data quickly. If WEF or EPA would agree to be the clearinghouse for sharing experiences and results through their Web pages, then the information could be disseminated quickly. It is important to publish not only successes, but also failures, because the profession can learn as much from mistakes as it can from successes.

Each test basin needs to have a long-term monitor installed at the downstream end and a rain gauge situated within it; the same for the control basin. The concept is to gather rainfall and flow data from dozens of storms prior to rehabilitation, dozens of storms during rehab and dozens after rehab so that we can create a statistically meaningful relationship between rainfall and I/I before and after rehab, see Figure 2

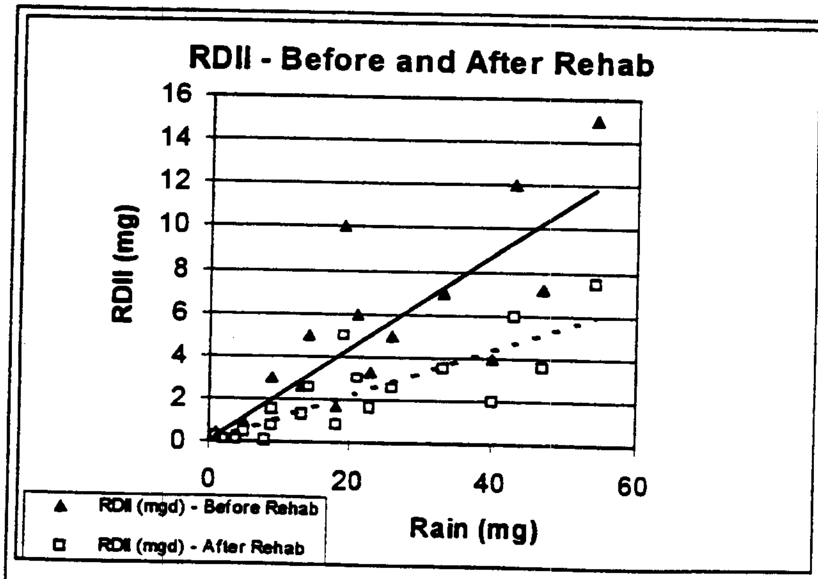

Figure 2

In this case rainfall and RDII data were taken from 20 storms before rehab shown by the dark triangles and also from 20 storms after rehab shown by the boxes. Both sets of data show a lot of scatter and they overlap. The solid trend line shows a linear regression estimate of RDII before rehab. The dashed line shows a linear regression estimate of RDII after rehab.

A control basin should also be set aside as a scientific control for the experiment. It serves the same function as a laboratory blank does in chemistry. The control basin should be left alone with no rehabilitation. The control basin helps account for the differences between a wet pre-rehab period and a dry post-rehab period or vice versa.[5]

By keeping the test basins relatively small, a community can limit its "experimental" expenditure on I/I reduction. If the rehab strategy works, then the strategy can be expanded to other parts of the collection system. If it doesn't then another rehab strategy can be tried without risking too much capital. Since each collection system is different, there is no assurance that what worked so well in Lower Paxton Township[4] in 1997, will work in Columbus. Small test basins also make the inevitable work on private property more politically palatable, since their are fewer building lateral owners to deal with. Finally, smaller basins allow engineers and municipalities to practice dealing with I/I migration issues on a small scale before trying to extend a possibly incomplete strategy to the rest of the collection system.

The downstream long-term monitor serves three other important functions. First, the people hired to find all the sources of I/I (sewer system evaluation survey) know that they need to look a little harder because they're being watched by the monitor. Second, the engineer hired to design the rehab project knows that he or she had better recommend effective rehab because they're being watched by the monitor too. And finally the contractors performing the rehab know that they better do the job just right, because they're also being watched. A little accountability goes a long way and this industry needs it.

Engineers who have tried to compare before and after rainfall and flow data from sewer rehabilitation projects know the difficulties and frustrations associated with trying to reach a simple conclusion. Many factors affect the rainfall-to-runoff relationship in a sanitary sewer, so there is inevitably a wide scatter in the data, again see Figure 2 above. Factors most affecting the rainfall to runoff relationship within a basin include: 1) rainfall intensity, 2) antecedent moisture, 3) season, 4) storm duration, 5) surface water coverage, and 6) new construction or rehabilitation. In fact, the scatter caused by these 6 variables is often so wide that a simple comparison of a month's worth of I/I before rehab to a month's worth of I/I after rehab is highly unlikely to capture the true effectiveness of rehabilitation. The solution is to collect data from many, many storms before, during and after rehab. Test basin monitors, therefore, should stay in the ground for 1 to 4 years or more. Since the monitors and rain gauges need to operate for such a long period of time, they should be connected to phone lines. Collecting data for 25¢ per phone call is much less expensive than sending $70 per hour crews into the field to collect data.

The key units to measure are: 1) rainfall intensity, 2) rainfall duration, 3) rainfall derived I/I (RDII) rate, and 4) RDII volume. Figure 3 shows a graphical definition of RDII rate and volume. The key relationships to calculate are 1) peak rainfall intensity to peak instantaneous flow rate, and 2) rainfall volume to I/I volume. See Figure 3.

Engineers can use some interesting units of measurement for the above comparison. Peak rainfall intensity commonly measured in millimeters per hour or inches per hour can be converted to liters per second of rain or millions of gallons per day of rain (mgd). Converting rainfall rates into common wastewater flow units provides an unusual perspective on the immense amount of rain that comes out of the sky. It also makes direct comparisons quite easy.

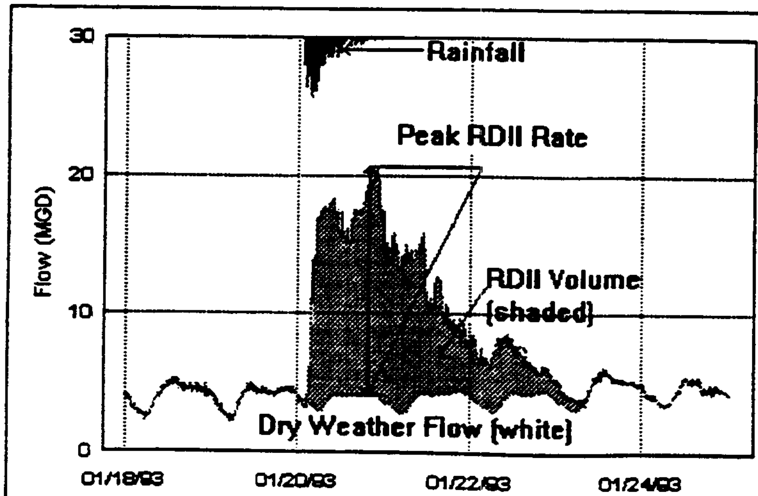

Figure 3

RESULTS

Two test basins have already been set up in Ohio: one in the Point Place neighborhood of Toledo and

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one in Erie County near the center of Huron. Both communities also have control basins. Each test basin and each control basin have a telemetered flow monitor and a telemetered rain gauge installed. Both sets of test basins in were set up in 1996 as part of the I/I monitoring.

Toledo performed Sewer System Evaluation Survey work in Point Place in 1996 and early 1997. Scott Weasel, P.E. and Jim Breznai, P.E. from Peterman and Associates out of Findlay, Ohio were the Engineers. ADS Environmental Services performed the fieldwork under subcontract to Peterman. Based on the results of the SSES, Peterman recommended replacing the storm sewer in the test basin because it was structurally deteriorated and its outlet to Maumee Bay was plugged. Fieldwork also indicated that the storm sewer surcharged and leaked indirectly and profusely into the sanitary sewer mains and laterals during rainstorms. The storm sewer was replaced and 6 of the 54 building laterals were also replaced, within the right-of-way, in October and November 1997.

Pre-rehab analysis of 25 storms dating from December 1996 through October 1997, shows that RDII rates averaged 22.6% of the rain falling on the ground. The standard deviation was 17% indicating a wide scatter in the data. Post-rehab analysis of 6 storms between November 13, 1997 and January 4, 1998 yielded an RDII rate of 10.4% with a standard deviation of 4%. This means that rehabilitation removed an average of 54% of the RDII in the test basin. The preliminary certification letter from Peterman and Associates conservatively claimed only a 50% reduction in I/I.

This is the first time that sewer rehabilitation in the state of Ohio has achieved documented success of 50% or more. These results give the City of Toledo confidence that sewer rehabilitation can successfully remove large amounts of I/I from their collection system.

Four more test basins and control basins are scheduled to be installed in Ohio in 1998, 2 in Columbus and 2 in Clermont County. Hopefully all four municipalities will be able to share their experiences, both positive and negative, through a WEF Web site or an EPA Web site.

CONCLUSIONS

1. I/I reduction is more effective than most people think. The average reduction reported from 91 basins worldwide is 49%. Twelve basins exceeded 75% reduction.
2. Test basins should be used to check out sewer rehabilitation strategies on a small scale before committing a community to a large-scale program that may be incomplete and ineffective.
3. Before-rehabilitation results should be reported many, many storms of varying intensities. Likewise, after-rehabilitation results should be reported from a similar number of storms. Control basins should be used to account for differences in antecedent moisture between the before-rehabilitation data set and the after-rehabilitation data set.
4. Reports on rehabilitation results should include enough standard information about the project for other communities to learn about the scope needed for effective rehabilitation. Reports could benefit the most people by being posted on a World Wide Web site set up for sewer rehabilitation.
5. Based on the results of the test basin, the City of Toledo knows that it is possible to reduce RDII in a neighborhood by over 50%. Stated differently, the City knows that plugged storm sewers can create enormous amounts of indirect I/I into the sanitary sewer system. Replacing the storm sewer and also replacing some of the sanitary laterals beneath the storm sewer can reduce the RDII rate by 50% or more.

FOOTNOTE

Test basins are not a new idea. USEPA in "*Facilities Planning 1981*" Section 5.4.4, states: "*For projects where large ... scale work is proposed the recommended approach is rehabilitating first a selected sample of sewers or a small subsystem. Analyze the results of the pilot rehabilitation to be sure the benefits are attained before conducting a full scale rehabilitation.*" USEPA thought of this idea 16 years ago, but its value is just now becoming apparent.

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THE INSPECTION OF SURCHARGED SEWERS USING SONAR TECHNOLOGY

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ABSTRACT

In recent years, sewer rehabilitation efforts adopted by many municipalities throughout the United States, especially in older cities where wastewater collection systems are approaching their life expectancy, are based on similar assessment techniques. The ability to inspect aging sewer lines in a manner that would provide useful information to engineers and professionals is a major challenge. In addition to the typical smoke testing, dye flooding, and closed circuit television (CCTV) methods used to assess the condition of the gravity sewer systems, sonar inspection (a new emerging technology) is beginning to get recognition in the United States. Used in Europe for over 10 years, this new method of inspection, survey, and evaluation is providing valuable information to engineers on sewer lines that are fully or partially submerged and unable to be inspected by other methods. For example, estimating the amount of silt accumulation in any segment of a sewer line has always been desired in order to prioritize cleaning operations, but considered impossible. The new sonar technology can not only provide estimations of silt accumulation but can actually measure it. In this paper, the authors introduce this exciting new inspection technology, provide a historical background on its development, and explain the makeup of its components. The paper also demonstrates how high-resolution sonar gives an internal cross-section profile of a sewer, so that a pipeline can be surveyed and fully assessed, including measuring the magnitude of defects. An inspection project in the City of New Orleans that successfully utilized the use of sonar technology combined with typical CCTV is presented and discussed as a case study. Videotape that shows the findings of Totally Integrated Sonar and CCTV Inspection Technique (TISCIT) will be available as background material. Sonar and TISCIT, with their ability to assess the condition of partially submerged sewers (CCTV system being positioned above the waterline and the sonar below resulting in a 360-degree survey of the pipeline), are new approaches to sewer inspection.

BACKGROUND

The advent of surveying sewer pipelines with Closed Circuit Television (CCTV) in 1965 became a great boon to pipeline engineers as they could, at last, plan system maintenance in advance of pipelines collapsing. They could also help in improving the longevity of the pipelines by rehabilitating damaged pipelines based on the defects found and the environment in which the pipelines exist (i.e., its strategic importance). This development created an immediate market in rehabilitation and renovation techniques of which now there are solutions for almost any situation found in the pipeline.

Because pipeline engineers could plan renovation and remedial measures, the need for more information about the pipelines increased, which caused a dramatic increase in the number of CCTV surveying companies offering their services. With the accumulation of so much data and the desire to capture more, it soon became apparent that the CCTV survey techniques available at the time were limited. The restrictions were generally related to the inability of the CCTV camera to survey pipes greater than 60 inches in diameter, the inability of the CCTV camera to "see" under the water line (in case of sewers that are difficult to de-water), and the inability of the CCTV camera to accurately measure the degree of pipe deformation. These restrictions were addressed by a number of companies as follows:

a. With the use of charged-coupled device chips instead of the tube inside the CCTV camera, the sensitivity greatly increased over the years as technology advanced. This advancement meant that CCTV cameras could now survey pipes in excess of 120 inches in diameter. The development of the "Pan and Tilt" type cameras increased this ability even further.

b. In 1988, the United Kingdom's Water Research Center (WRc), Amtec Surveying Inc. (Amtec), and MEL Inc. (a British offshore sonar company) developed a short range, high resolution, sonar system giving continuous survey information on the condition of pipelines below the water line. The sonar can be used alone for fully surcharged pipelines, or in conjunction with a CCTV camera for semi- surcharged pipelines (CCTV above the water line and sonar below resulting in a 360-degree survey of the pipeline). This method is called the Totally Integrated Survey and CCTV Inspection Technique (TISCIT).

c. LightLine, a method developed by Amtec, enables the shape of the pipe to be accurately profiled and measured. LightLine enables "pinch points" to be measured along the pipeline where more accurate dimensions are required. It is a particularly effective method for surveying plastic pipes (or any other flexible material pipe) where measuring deformation by CCTV is ineffective.

SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM

The Sewerage and Water Board of New Orleans (S&WB) is implementing a multi-year Sewer System Evaluation and Rehabilitation Program (SSERP). The purpose of this program is to eliminate sewer system overflows by fixing the major structural defects in the collection system. The SSERP will also address the collection and transmission system bottlenecks by upgrading pipeline carrying capacity utilizing a system-wide hydraulic model.

Several Collection System Evaluation Studies (CSES) are planned to provide physical assessments of the gravity sewer conditions. These CSESs include the typical techniques of sewer inspection and survey such as smoke testing, dye flooding, flow monitoring, night flow isolation and CCTV. However, due to the age of the New Orleans sewer system (over 100 years old) and to the fact that some large diameter sewer lines were impossible to de-water for normal CCTV, new techniques were researched and evaluated which led to the use of sonar technology as a pilot project.

PILOT PROJECT

The S&WB's Clara Street sewer is one of the key gravity lines in the New Orleans collection and transmission system. This sewer line carries the flow of multiple interceptors that collect wastewater from the Carrollton, Uptown and Central Business District (CBD) service area basins. The Clara Street sewer line is constructed of mostly brick and is more than ninety (90) years old. This sewer is approximately 22,000 feet of 36-inch diameter to 84-inch diameter pipeline that terminates at the regional sewer pump station ("A") . The objective of this pilot project was to internally inspect, survey and evaluate the Clara Street sewer using the Sonar and TISCIT systems. Another objective was to establish the ability to document and determine the interior condition of pipes in varying material, shape, and size from the data generated by this technique.

TECHNOLOGY USED

Sonar System

The Sonar System used in this project was specifically designed for the survey of submerged pipelines in that it uses high resolution/short range sonar. High-resolution sonar gives an internal cross sectional profile of a sewer, so that the pipeline can be surveyed and fully assessed, including measuring the magnitude of defects. The system itself is capable of surveying pipelines that vary in size from eight inches to in excess of 18 feet in diameter.

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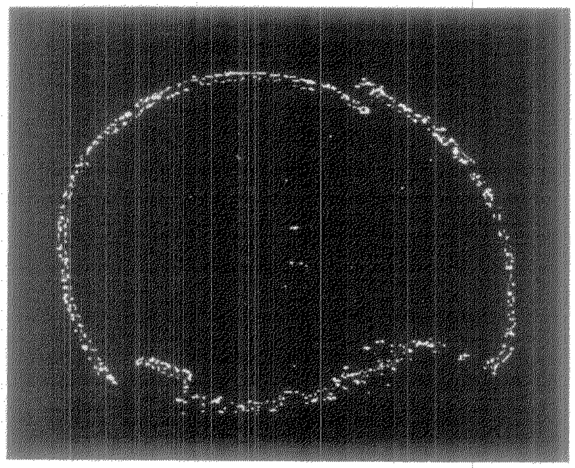
The head of the sonar, its transducer, looks sideways (at right angles) to the direction of the motion through the pipe, resulting in one cross-sectional view of the pipe every second in "real time". The image below shows a 36-inch pipe with a break resulting in deformation of approximately 15 percent of the original pipe diameter. The image also shows heavy and compacted silt in the invert denoted on the sonar screen by the coloring (in cases where silt accumulation is less compacted, the coloring in the invert would be blue).



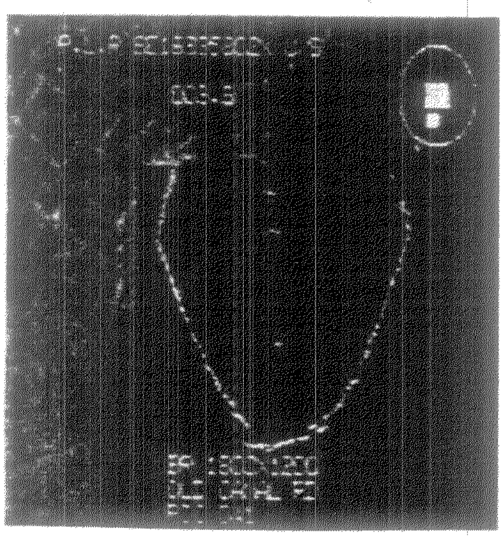
- The image on the left shows a 36-inch pipe with a break at 1 o' clock, resulting in deformation of approximately 15 percent.
- There is heavy compacted silt in the invert denoted by the coloring (if the siltation was less compact then the coloring in the invert would be blue).

TISCIT

This system is the combined technology of CCTV and high-resolution sonar that provides composite views of partially submerged sewers. TISCIT is an acronym for:

Totally **I**ntegrated **S**onar and **C**CTV **I**nspection **T**echnique

The CCTV system is positioned above the water line and the sonar below the water line resulting in a 360-degree survey of the circumference pipeline. The sonar image is superimposed onto the CCTV picture using a "mixer" which enables the rig manager to see both above and below the water line on one monitor. The image below shows a typical result from a TISCIT survey with the invert of the pipeline superimposed in the middle of the CCTV picture.



- A typical result from a TISCIT survey with the invert of the pipeline superimposed in the middle of the CCTV picture.
- Once a defect or feature is noted in the invert, the sonar image can be captured to disk to be subsequently viewed and measured in the office.
- The sonar image is removed periodically so that the line of the pipe can be seen.

This system can only be applied to pipes sized greater than 24 inches in diameter and would then be subject to the water level. As the speed of inspection is critical for the longitudinal resolution, the general guideline for the speed of survey is approximately four inches per second.

The sonar uses a color display to indicate the type of surface the sonar is sweeping, denoted by red for a hard surface and blue for a softer surface.
As with the CCTV system, the method of propulsion for the Pilot Project was either self- propelled or floated depending upon known circumstances in the pipeline, or the pipe size as follows:

- If heavy silt is expected, then pipelines above 24 inches would be surveyed by the sonar being floated along the crown of the pipe.

- If the pipeline is less than 24 inches, then either the self-propelled or winch- assisted self-propelled method would be used.

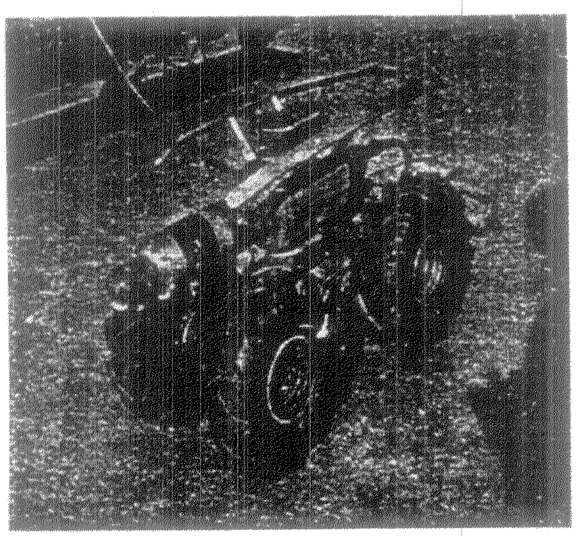
OVERVIEW OF EQUIPMENT

An experienced field team consisting of four individuals (a team leader, rig manager and two rig operators) was assembled to carry out the inspection for the Pilot Project. This team used a survey rig, generally referred to as the "Special Rig" to survey pipelines which range from "dry" all the way through to fully surcharged. This rig has the following survey propulsion methods:

- Self-Propelled
- Winched on Skids
- Floated (CCTV and Sonar or Sonar only)
- Winch-assisted Self-Propelled

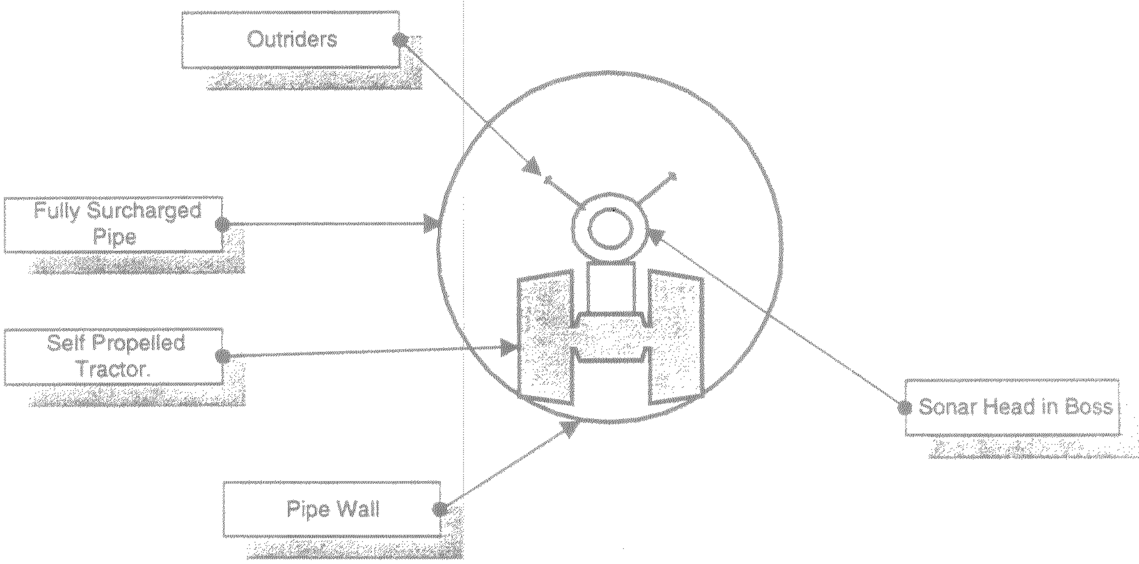
The following survey methods were used in the inspection of Clara Street sewer line:

1. Sonar only, self-propelled system; applied to fully surcharged pipelines

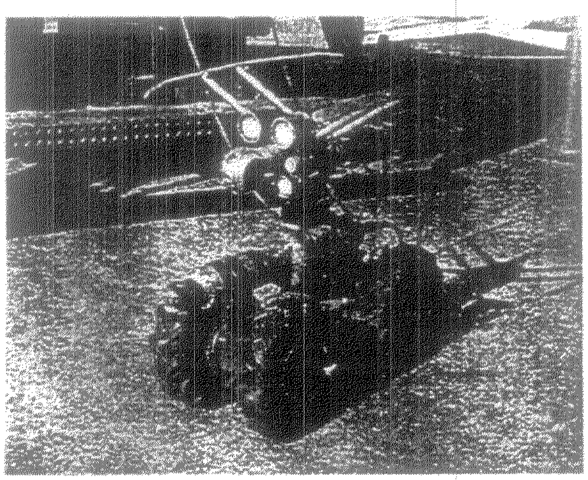


- This method was applied to the pipelines 36 inches in diameter or greater.
- Note the size of wheels which assists in the negotiation of siltation and the "outriders" which ensures the equipment's stability should it "fall" to one side.
- The block between the outriders is where the CCTV camera would be attached to should the need for TISCIT arise.

Set up for Sonar Only. Fully Surcharged. Self Propelled method.

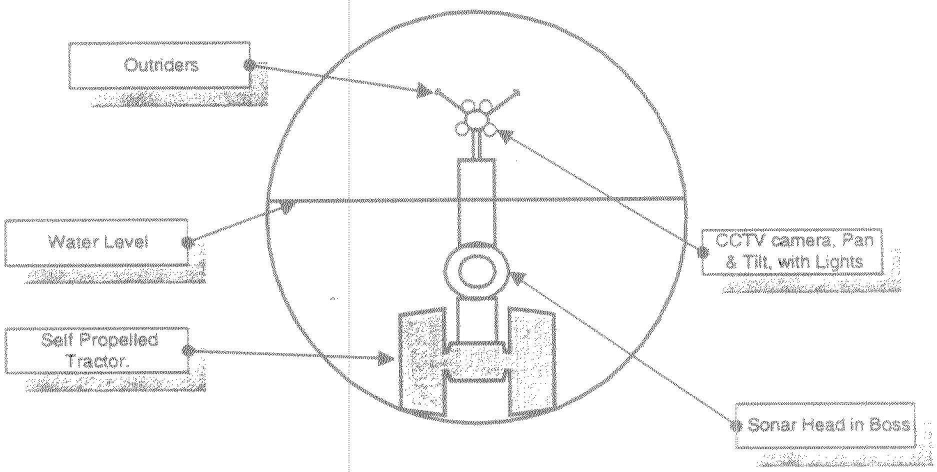


2. **TISCIT, self-propelled system. Applied to semi surcharged pipelines.**

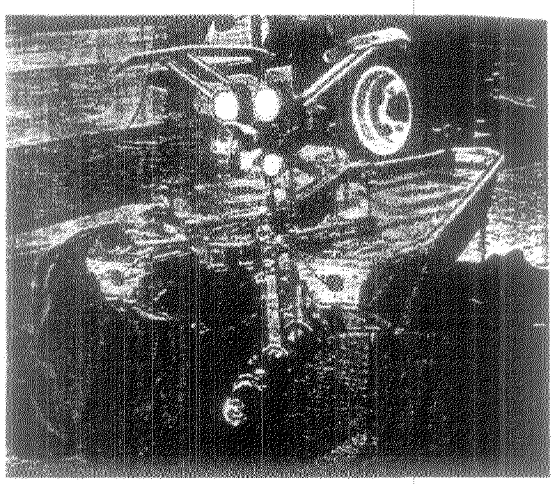


- This method was applied to the pipelines 36 inches in diameter or greater.
- Note the size of wheels which assists in the negotiation of siltation and the "outriders" which ensures the equipment's stability should it "fall" to one side.
- Building Blocks can be added between the camera and the sonar depending on the water level and pipe size.

Set up for CCTV/Sonar Combined. TISCIT. Self Propelled method.



1. **TISCIT, float and winched system; applied to semi-surcharged pipelines that are greater than 36 inches in diameter.**



- This method was applied to pipelines greater than 36 inches.
- The distance between the floats can be changed to suit the size of pipe as can the distance between the sonar and the camera by using "spacer bars".
- A single float can be used where the pipe size allows such a set up.
- This method is not hampered by silt deposits.

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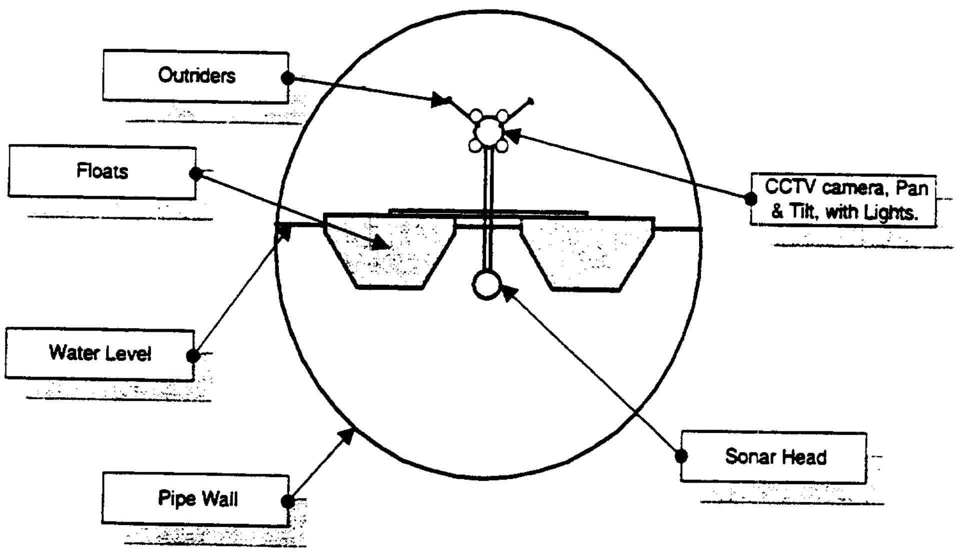
Set up for CCTV/Sonar Combined. TISCIT Floating Method. 360 degree coverage.



Larger Sizes set up. Two floats.

COLLECTION OF DATA

In order to collect the data and analyse it in an organized, uniform way, a coding system that is based on the Manual of Sewer Condition Classification (prepared by the United Kingdom Industry Engineering and Operations Committee) was adapted and utilized for this project. This coding system rates each defect feature based on defect magnitude (or severity). Table 1 lists some of these sewer condition codes.

For the Pilot Project, the rig manager complete a report sheet (field sheet), per survey, on site which was subsequently imported into a data handling software. The software had a very high level of validation that resulted in more accurate data. The collected data was then imported into a data interrogation software (Examiner, by Amtec) for subsequent analysis.

TABLE 1. **Sewer Condition Codes**

CODES	DEFINITIONS
BCL(J)	Crack longitudinal at ... o'clock (at joint)
CC(J)	Crack circumferential from ... to ... o'clock (at joint)
CM(J)	Cracks multiple from ... to ... o'clock (at joint)
FL(J)	Fracture longitudinal at ... o'clock (at joint)
FC(J)	Fracture circumferential from ... to ... o'clock (at joint)
FM(J)	Fractures multiple from ... to ... o'clock (at joint)
B(J)	Broken pipe at ... (OR from ... to ...) o'clock (at joint)
H	Hole in sewer at ... (OR from ... to ...) o'clock
D	Deformed sewer ... %
DH	Deformed sewer ... % loss of horizontal dimension
DV	Deformed sewer ... % loss of vertical dimension
X	Sewer collapsed ... % cross-sectional area loss
JDS	Joint displaced slight
JDM	Joint displaced medium
JDL	Joint displaced large
OJS	Open joint slight
OJM	Open joint medium
OJL	Open joint large
SSS	Surface damage, spalling slight at ... (OR from ... to ...) o'clock
SSM	Surface damage, spalling medium at ... (OR from ... to ...) o'clock
SSL	Surface damage, spalling large at ... (OR from ... to ...) o'clock
SWS	Surface damage, wear slight at ... (OR from ... to ...) o'clock
SWM	Surface damage, wear medium at ... (OR from ... to ...) o'clock
SWL	Surface damage, wear large at ... (OR from ... to ...) o'clock
MS	Mortar missing surface at ... (OR from ... to ...) o'clock
MM	Mortar missing medium at ... (OR from ... to ...) o'clock
MT	Mortar missing total at ... (OR from ... to ...) o'clock
DB	Displaced bricks at ... (OR from ... to ...) o'clock
MB	Missing bricks at ... (OR from ... to ...) o'clock
DI	Dropped invert, gap ... mm
RF(J)	Roots fine (at joint)
RT(J)	Roots tap (at joint)
RM(J)	Roots mass ... % cross-sectional area of loss (at joint)
IS(J)	Infiltration seeper at ... (OR from ... to ...) o'clock (at joint)
ID(J)	Infiltration dripper at ... (OR from ... to ...) o'clock (at joint)
IR(J)	Infiltration runner at ... (OR from ... to ...) o'clock (at joint)
IG(J)	Infiltration gusher at ... (OR) from ... to ...) o'clock (at joint)
EL(J)	Encrustation light from ... to ... o'clock (at joint)
EM(J)	Encrustation medium from ... to ... o'clock ... % cross-sectional area loss (at joint)
EH(J)	Encrustation heavy from ... to ... o'clock ... % cross-sectional area loss (at joint)
ESL	Scale light from ... to ... o'clock
ESM	Scale medium from ... to ... o'clock
ESH	Scale heavy from ... to ... o'clock
DE(J)	Debris (non-silt/grease) ... % cross-sectional area loss (at joint)
DES(J)	Debris silt ... % cross-sectional area loss (at joint)
DEG(J)	Debris grease from ... to ... o'clock ... % cross-sectional area loss (at joint)
OB(J)	Obstruction ... % height/diameter loss (at joint)
WL	Water level ... % height/diameter loss
LL	Line of sewer deviates left
LR	Line of sewer deviates right
LU	Line of sewer deviates up
LD	Line of sewer deviates down

DESCRIPTION OF DEFECTS

Eighty-seven (87) surveys were attempted throughout the Clara Street sewer line. Seven-five (75) surveys were successfully completed and twelve (12) survey attempts were abandoned due to debris and excessive silt accumulation. The following describe and summarize some of the defects found during Sonar/TISCIT inspections.

Structural Defects

Structural performance refers to the structural integrity of the system. Structural defects may ultimately worsen, resulting in failure by sewer collapse. Some structural defects are defined below as:

- Cracks and Fractures

Cracks can be identified as lines visible on the sewer wall, with the pieces of the wall still in place. A crack may be either longitudinal (i.e., following the longitudinal axis, or length, of the sewer), or circumferential (i.e., around the periphery of the sewer). Cracks are not serious defects, but are indicative of the initial stages of sewer deterioration. Multiple cracks are a combination of both longitudinal and circumferential cracks.

Fractures may be identified where the wall of the sewer is visibly open along the length and/or circumference of the sewer, with the pieces of the sewer wall in place. As with cracks, a fracture may be longitudinal or circumferential. The sewer may be seen to suffer from some distortion. The defect is indicative of the secondary stage of sewer deterioration and constitutes a more serious problem than a crack. Multiple fractures are a combination of both longitudinal and circumferential fractures.

- Broken Pipes

When broken pipes are encountered, pieces of the sewer conduit are noticeably displaced, differentially, and some pieces could be missing. Thus, a hole in the fabric of the sewer is also classified as broken. A broken sewer is the most structurally serious defect. A chipped sewer wall is not considered broken, but should be noted and kept under observation for possible further development into a break.

- Deformed or Collapsed Pipes

Deformation of a pipe is a measure of the vertical and horizontal reduction or change in the cross-section of a sewer as a result of self-weight or external forces. Three levels of deformation are normally observed:

<u>0-5 percent deformation</u> is acceptable, may not need structural upgrading, and normally requires monitoring.
<u>5-10 percent deformation</u> requires some form of structural enhancement, possibly a lining; and
<u>10 percent deformation</u> is a collapse condition and the sewer should be replaced.

- Displaced or Open Joint

A displaced joint is one in which adjacent conduit sections are not concentric. An open joint is one in which adjacent conduit sections are open. Displacements are observed as a fraction of the wall thickness (t) of the conduit as follows:

<u>Slight</u>	$< t$
<u>Medium</u>	$< 1.5\ t$
<u>Large</u>	$> 1.5\ t$

- Corrosion

A sewer conduit may be damaged in various ways, including spalling, wear, erosion, or by any deleterious mechanism.

Service Defects

Service performance relates to the ability of the system to perform its intended function, i.e., convey wastewater. Problems that impair service performance include severe root intrusion, debris accumulation, sags in pipes, etc. These types of problems are typically not considered structural defects, but nonetheless can result in operational failures of the system due to blockages and resultant flow backups and overflows.

- Infiltration

Groundwater that enters the wastewater collection system through defective pipes, pipe joints and manhole walls is classified as groundwater infiltration. The magnitude of groundwater infiltration depends on the condition of the collection system components, the depth of the groundwater table with respect to the defects, and the percentage of the collection system that is submerged. Variation in groundwater levels and subsequent groundwater infiltration is normally seasonal. Groundwater infiltration will be a relatively constant volume throughout individual seasons. Groundwater infiltration will be greater in the rainy seasons when the water table is high and less in the dry seasons when the water table is low. Where sewers are constructed in year round swampy areas, or in proximity to and below the level of major creeks or other water bodies, groundwater infiltration will be relatively constant during all seasons.

The various levels of ground water infiltration may be identified as follows:

Seeper - The slow ingress of infiltration through sewer or manhole structure, identified by a glistening effect of the water under the influence of a survey lighting apparatus;
Dripper - Infiltration characteristically dripping into the wastewater system through sewer or manhole structural defects;
Runner - Infiltration running into the wastewater system through sewer or manhole structural defects;
Infiltration - Infiltration entering the wastewater system under hydrostatic pressure via structural defects.

- Roots

Root intrusion may occur through defects of sewer conduits, laterals, or manholes, and can be described as fine, mass, or tap roots depending on severity.

Fine roots - are slender or fibrous roots that result in a partial reduction in hydraulic capacity;
Mass roots - are a formed congealed density of roots that restrict flow; and
Tap roots - are individual root strands over 12.5 mm thick.

- Debris

Debris includes grease, rocks, sand, and silt in a sewer line, excluding items mechanically attached to the line (e.g., intruding service connections or intruding pipe and joint materials). Debris can cause turbulence in the sewer conduit and a reduction in hydraulic capacity.

Debris is normally identified by the following characteristics:

General (e.g., rocks, grease)
Mechanical
Structural

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Strata (e.g., sand, silt)

The estimated amount of silt accumulation identified in the Clara Street Sewer Pilot Project is shown in Table 2 below:

Table 2. **Silt Accumulation in Clara Street Sewer**

Amount of Silt	**Approximate Distance Affected**
Less than 3 inches	11,000 feet
Between 3 inches and 5 inches	6,000 feet
From 5 inches to 12 inches	5,000 feet

Construction Defects

Construction defects include those defects relating to junctions, connections, and manholes. They sometimes fall under the category of service defects, since they can impair the service performance of the system.

- Connection

Have become damaged during or after construction,
Are incorrectly positioned,
Are of poor workmanship, or
Obstruct the flow, causing a reduction in hydraulic capacity and efficiency.

- Intruding Connection

An intruding connection is one in which the connection intrudes into the sewer and has become damaged during or after construction, causing a reduction in hydraulic capacity and efficiency. Most intruding connections are defective.

DEFECTS SUMMARY

Table 3 provides a listing of some major defects identified from the Clara Street Inspection along with the number of their occurrences.

Table 3. **Major Defects**

Defects	Number of Occurrences
A – Structural	
Breaks	1
Crack – Circumferential	9
Crack – Longitudinal	7
Deformed	2
Displaced Brick(s)	65
Fracture – Circumferential	10
Fracture – Longitudinal	4
Hydro Sulphide Attack Heavy	1
Hydro Sulphide Attack Medium	3
Joint Displaced Large	1
Joint Displaced Medium	1
Missing Brick(s)	24
Mortar Missing Medium	8
Open Joint Medium	2
Surface Wear	48
B – Service	
Debris	501
Infiltration Running	1
Obstruction	20
C – Construction	
Connection Intruding	2

CONCLUSION

The Sonar/TISCIT technology has enabled inspection of the surcharged Clara Street sewer line for the first time since its original installation more than 90 years ago.

The locations of defects varying from broken segments of the pipelines, longitudinal and circumferential cracks, displaced and missing bricks, longitudinal and circumferential fractures, displaced joints, corrosion, intruding connections, debris, infiltration, and obstructions were identified and recorded using Sonar/TISCIT. This inspection technology also assisted in better estimating the amount of silt accumulation in various parts of the sewer line.

Superimposing a captured sonar image of a particular line segment onto a CCTV picture allowed the engineers to see both above and below the water line resulting in a 360–degree survey of the sewer. Determining the severity of deformation for an existing pipe is another valuable feature this technology provides. This was accomplished by utilizing tools that plot the exact cross-sectional figure of the pipe (based on its original diameter) and then comparing it with a sonar image of the existing sewer. The same tool measures the depth of silt accumulated in the bottom of the sewer providing more accurate debris quantification.

The Sonar/TISCIT technology has proven to be a valuable method for surcharged sewer inspection. This technology's ability to detect, identify, and locate defects in sewer lines that are partially or fully submerged is both effective and efficient. The ability to quantify the amount of silt accumulated in various sections of sewer lines utilizing Sonar/TISCIT helps prioritize sewer cleaning efforts. It has been recommended that the Sewerage and Water Board of New Orleans adopt these technologies for all future surcharged sewer line inspections, rehabilitation and cleaning tasks.

BASEMENT FLOODING- SALEM, OREGON'S EXPERIENCE

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ABSTRACT

In recent years, a significant number of residents in the City of Salem, Oregon have had the unpleasant experience of finding raw sewage backed up in their basements. The City of Salem has an aging sanitary sewer collection system which experiences extensive surcharging during rainfall events.

It is estimated that as many as 500 homes within the City are experiencing basement flooding due to sanitary sewer backups. During the winter of 1996-97, the City initiated an investigation of eight selected neighborhoods and identified alternatives for reducing or eliminating basement flooding. The investigation consisted of surveying customers, inspecting sewer lines, smoke testing, and flow monitoring. City staff worked closely with the neighborhoods in finding a solution.

As a result of the investigation four alternatives were identified which would reduce or eliminate basement flooding from sanitary sewage. These alternatives include:

A. Rehabilitation/Replacement (R/R) of significant portions of the sewer collection system in selected neighborhoods including replacement of sewer laterals.
B. Infiltration/Inflow reduction program using grouting, sliplining, spot repairs, etc.
C. Modify the interior plumbing of the home and install a backwater valve.
D. Modify the interior plumbing of the home and install a new service and ejector pump.

Alternatives C and D were selected since they provide the highest level of protection at the least cost. These alternatives allow sewer mains to surcharge without flooding area basements and bring older homes up to current plumbing code standards.

As a result of the investigation, the City of Salem implemented the Positive Protection Program. This program provides technical assistance to the homeowner and zero interest loans for making needed improvements which protect the basement from future storm events.

Approximately 100 home owners are currently signed up for the program. The City has budgeted $790,000 for the initial year of a multi-year program. Total cost is estimated at $4.0 to $5.0 million.

KEYWORDS

Sewer backup, infiltration, basement flooding, rehabilitation, backwater valves, ejector pumps, Positive Protection Program.

INTRODUCTION

The City of Salem, Oregon is located in the heart of the Willamette Valley. The City operates a regional wastewater treatment facility which provides service to approximately 183,000 people including the City of Keizer and several unincorporated areas. The wastewater collection system consists of approximately 1,094 km (680 miles) of sewer mains and 30 pump stations. Main lines consists primarily of concrete pipe 15.2 cm (6 inches) to 1.9 meters (75 inches) in size. Portions of the collection system date back to the late 1800s.

The City has a rehabilitation and replacement (R/R) program which concentrates on replacing undersized or structurally deficient portions of the collection system. Follow up studies on some of the City's earlier R/R projects indicated only a minimum amount of success in reducing groundwater infiltration when sewer service laterals were not upgraded along with the sewer mains. Since 1990, the City has included as an integral part of all R/R projects, replacement of the sewer service laterals from the main to the house, at public expense.

Salem residents are accustom to wet winter weather since the area receives nearly 102 cm (40 in.) of annual precipitation. However, 1996 was a record year with approximately 152 cm (60 in.) of rainfall. This included a February storm event which lasted for over a week and included four consecutive days with over 6.0 cm (2.4 in.) of rainfall. Statistically this is equivalent to an 80 to 100 year storm event. The City experienced extensive surface flooding in addition to many flooded basements and was forced to shut down the treatment plant for a short period of time. Salem hasn't experienced a storm of this magnitude in over 30 years.

While still recovering from the February storm event, the City experienced another large storm in November 1996. During this storm event, 11.5 cm (4.52 in.) of rain fell over a two day period. This amount of rainfall is in excess of a 50 year storm event. In addition to these two large storms, six other smaller but major storms helped make 1996 the wettest year on record. Meteorologists are predicting that the next 20 years will be wetter than normal.

In recent years basement flooding from sanitary sewer backups has resulted in a great deal of frustration on the part of the property owners as well as Public Works staff who maintain and operate the sewer collection system. In November 1996, a large group of citizens went before the City Council requesting that a solution be found regarding basement flooding and the City made a commitment that this problem would be resolved.

Sewage backing up into a basement could be caused by grease, roots, or other types of blockages in a sewer main. Effective maintenance programs have contributed to the relatively rare occurrence of this type of problem which can normally be corrected in a short amount of time.

A more common and difficult cause of basement flooding results from an excessive flow in sewer lines during periods of heavy rainfall. This results in the carrying capacity of the sewer line being exceeded, backing up the flow in the sewer mains and eventually ending up in basement storage and living areas. The excessive flow results primarily from infiltration of groundwater which enters the sewer lines through cracks, holes, and joints in the pipes. Older homes may also have their footing drains attached to the sewer service lateral resulting in a large source of infiltration. Inflow may also contribute to sewer surcharging, but is not believed to be the primary source of excessive water within the Salem collection system. Inflow results from direct connections with surface water, such as roof drains, catch basins, open cleanouts, etc.

A typical plumbing system for an older home in Salem with a basement is illustrated in Figure 1. Plumbing from the upper floor of the home is typically tied into the basement plumbing resulting in a common service line which runs under the basement floor and continues to the sewer main located in the alley or street. As illustrated in Figure 1, in many homes the basement floor is often less than a meter above the top of the sewer main. In this situation, only a relatively minor surcharging event can result in significant basement flooding. Even a few centimeters of water within a basement living area may cause extensive damage. Many homeowners have indicated to the City that any incidence of basement flooding from sanitary sewer backups is unacceptable.

METHODOLOGY

During the November 1996 storm event, 160 residents throughout the City reported to Public Works that their basements were flooded from a sanitary sewer backup. Many more residents are believed to have experienced basement flooding but chose not to report it to the City. It is estimated that as many as 500 homes within the City could be experiencing basement flooding from sanitary sewage. Many of these homes have experienced flooding on a frequent basis even for relatively small storm events.

Typical plumbing system for an older home with a basement.

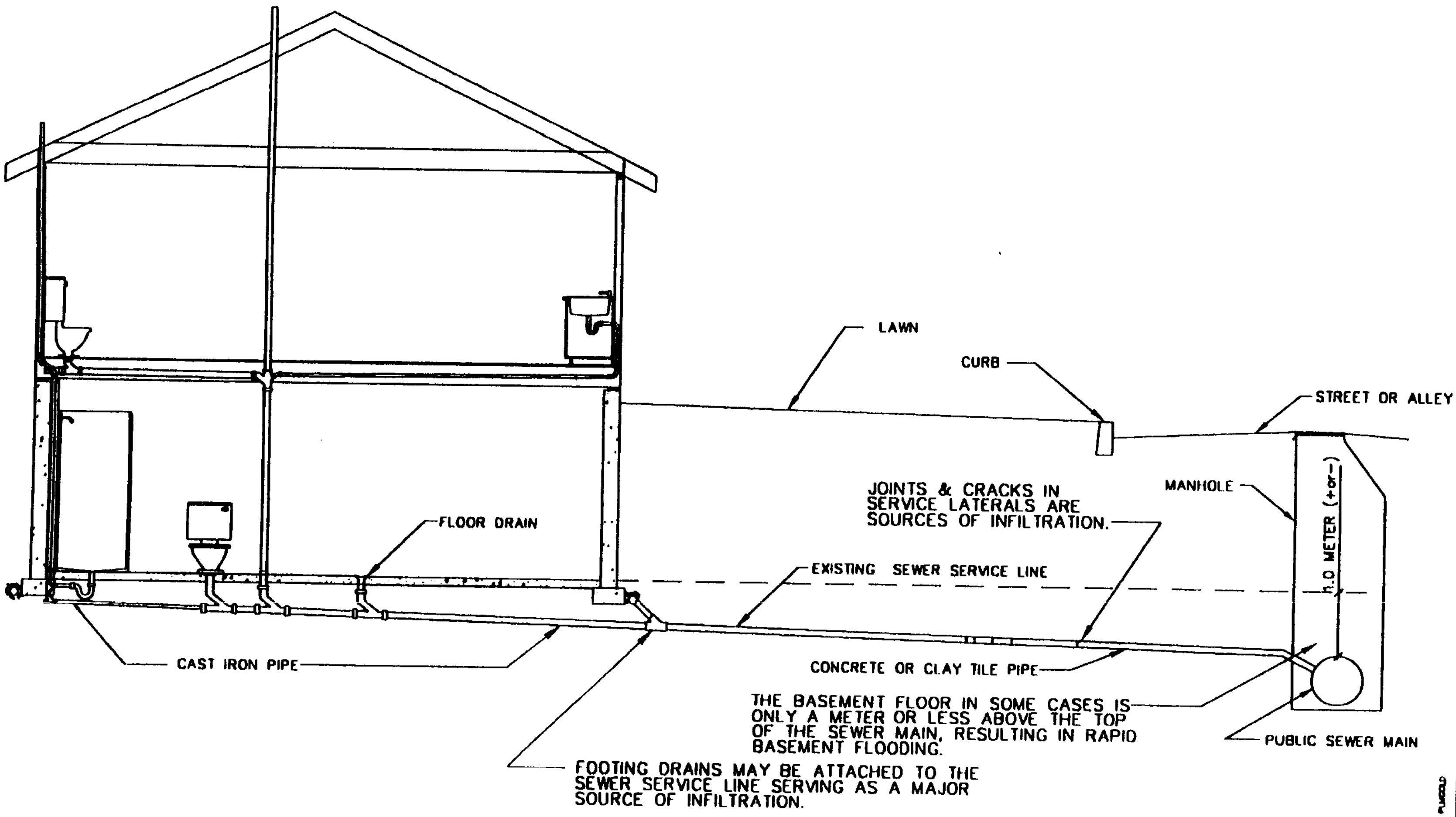

Figure 1

In December 1996, the City of Salem Public Works Department established an investigative team to identify alternatives for reducing or eliminating basement flooding resulting from sewer backups. A total of eight neighborhoods were included in the field investigation. Study areas were prioritized based on the number of incidences of basement flooding reported to the City. The investigative team consisted of engineers and technicians in both the Engineering and Operations Divisions of Public Works.

The investigative process for each study area included:

- Surveying the neighborhood with questionnaires to determine the scope of the problem.
- Assessing the condition of the sewer lines via video inspection records.
- Monitoring sewer flows within the study area.
- Reviewing existing smoke testing records where available.

With this information, the investigation team was able to assess the overall condition of the sewer collection system and determine where basement flooding was taking place. Informational meetings were held with the affected neighborhoods to report the findings and recommendations.

Questionnaire/customer survey

Questionnaires were sent to all residences in each selected neighborhood. The purpose of the survey was to determine which homes had a basement and of those homes which ones were experiencing basement flooding caused by sanitary sewer backups. The survey also gathered information about the number and type of fixtures in the basement and whether a backwater valve had previously been installed.

Results from the questionnaires were supplemented with a "windshield survey" in order to quantify the number of homes having a basement within the study area. Survey information was used to estimate the total number and location of homes within each neighborhood which were experiencing basement flooding. Results of the each survey was visually displayed on a map using the City's Geographical Information System (GIS).

TV investigation

A video inspection of all sewer mains was performed within each study area. This investigation was used to determine the overall condition of the lines and determine if there were any restrictions which could have contributed to the basement flooding.

Much of the TV inspection was conducted during the winter months while groundwater levels were high. Clear water was noted to be flowing from many of the sewer service laterals in basement flooding areas. Many of these services are 60 to 80 years old and installed at the time the home was constructed. Estimated flows from the services ranged from 0.06 to 0.32 liters/ sec (1.0 - 5.0 gpm).

As a result of the TV inspection each sewer main received a rating of good, fair, poor, or bad. Ratings were based on the overall structural condition of the pipe. Typically 20 - 25 percent of the sewer mains within the study areas were rated as poor or bad. Those lines considered to be in bad condition are structurally deficient to the point where rehabilitation of the line segment is warranted. Line segments in this category would typically have erosion along the inside of the pipe, holes, wide joints, large cracks and pieces of missing pipe. Typically the sewer service lines connected to these line segments are also in poor condition and a major source of groundwater infiltration.

Flow monitoring

Flow monitoring was used to determine the response of the sewer collection system to a rainfall event.

The City of Salem has a number of portable flow monitors which can be placed in a sewer mainline and provide a continuous measurement of flow at a particular site. Flow information can then be compared with the quantity of rainfall measured at one of the ten rainfall gauging stations located throughout the City.

The system response to a storm event is dependant on the time of the year. Heavy rainstorms in the fall will elicit a much different response then the same storm occurring during the winter months. Once the groundwater rises within the vicinity of the sewer line, the collection system appears to respond very quickly to a rainfall event increasing the possibility of basement flooding.

The flow monitoring results indicate that areas experiencing basement flooding typically have high peaking factors. The peaking factor is determined by dividing the peak wet weather flow by the peak dry weather flow. Peaking factors in the range of four to seven were not uncommon in basement flooding neighborhoods, depending on the magnitude and duration of the storm event.

Smoke testing results

The entire sewer collection system within the City of Salem was smoke tested twice during the 1970s and early 1980s. Numerous sources of inflow were removed during that time period.

Smoke testing results from 1994 where available for approximately half of the study areas. The results typically indicated that these areas did not have a high number of inflow sources (roof drains, catch basins, open cleanouts). However, smoke test results did indicate a high number of failing sewer service laterals and other sources of infiltration.

RESULTS

The following conclusions were reached as a result of the field investigation:

1. Basement flooding is most pervasive in the City of Salem within older neighborhoods located in areas with relatively flat topography.

2. A significant portion (20 - 25%) of the sewer collection system within the basement flooding areas is structurally deficient and needs to be replaced. However, the majority of the sewer mains within the problem neighborhoods are rated in good condition.

3. A large amount of rain induced infiltration appears to be widespread throughout the study areas. This conclusion was reached on the basis of the field investigation, the number and location of flooded basements within each study area, and flow monitoring results.

4. A significant portion of the infiltration is believed to be coming from the sewer service laterals. This conclusion is based on observations made during the TV inspection of the sewer mains. As a result of follow up improvement projects, it was also learned that many older homes with basements have footing drains attached to the sewer service laterals.

5. In some locations there appears to be little elevation difference between many of the basements and the sewer main. Therefore, only a relatively minor amount of surcharging (one meter), or backup in the system can result in the basement flooding.

DISCUSSION

The alternatives evaluated for reducing basement flooding can generally be divided into two groups. The first group involves alternatives which would reduce the surcharging or backup within the trunk sewer system. These alternatives either provide additional trunk sewer capacity or reduce the amount of groundwater infiltration. By increasing capacity or reducing flow, these alternatives decrease or eliminate surcharging of the system, reducing the potential for system backups which causes the basement flooding the basement area from the remaining portion of the house. Backwater valves have been installed for a number of years, are fairly reliable, and require some annual maintenance.

The cost for Alternative C as illustrated in Figure 2 will vary depending on the amount of existing finish work in the basement. Those homes which have a fully finished living area in the basement are more expensive to retrofit with this type of system. A cost of $6,000 per dwelling, including $3,000 for a new service lateral, was used for estimating purposes.

Alternative D--Modify the interior plumbing of the home and install a new service and ejector pump.

This alternative includes the installation of a new sewer service line from the sewer main to the house. It also includes the installation of a new ejector pump system within the basement floor which pumps sewage from the basement area into the new sewer service line. This system allows the basement to be used under any surcharge conditions which are taking place within the trunk sewer line and is illustrated in Figure 3. This alternative may be more appropriate for those homes that have a bathroom in the basement living area or plan on constructing one in the near future.

Alternative D provides a lower risk of failure however, as with Alternative C, some maintenance is required. Ejector pump systems have been used in thousands of installations and have proven reliability.

This alternative results in major costs to retrofit the existing house plumbing, install new equipment, and provide a new sewer service lateral. Costs will vary depending on the amount of existing finish work in the basement and the location and length of the new sewer service lateral. More excavation and labor will be required for this installation than for Alternative C. Costs for Alternative D average about $10,000 per home in Salem including the cost of the new sewer service lateral.

Evaluation of alternatives

In order to evaluate and compare alternatives, the following criteria were used:

- Effectiveness- How effective is the alternative in keeping the basement from flooding from sewer backups?
- Timeliness- How fast can the alternative be implemented? It is likely that further basement flooding will occur in Salem during future rainy seasons which extend from October to April.
- Cost effectiveness- Do the benefits outweigh the costs for the selected alternative?
- Implementation- Is the alternative implementable? How easy is it to install and make operational?

Using this set of criteria, an evaluation matrix was used to rank the alternatives. Based on the selected criteria, Alternatives C and D ranked higher than Alternatives A and B. Alternatives A and B could reduce the amount of basement flooding which is occurring in the affected neighborhoods. However, it is unlikely that Alternatives A or B would ever eliminate basement flooding from occurring under severe conditions.

Alternatives C and D provide positive and relatively reliable protection against basement flooding caused by sewer surcharging even during severe conditions. Even if alternatives A or B were selected, some property owners would find it advisable or necessary to install backwater protection devices recommended under Alternatives C and D.

The modifications undertaken as a part of Alternatives C and D are relatively easy to implement and use proven technology. Most area plumbers have the experience and skill to install these facilities.

CITY OF Salem AT YOUR SERVICE

Alternative D: Modify the interior plumbing of the home and install a new service and ejector pump.

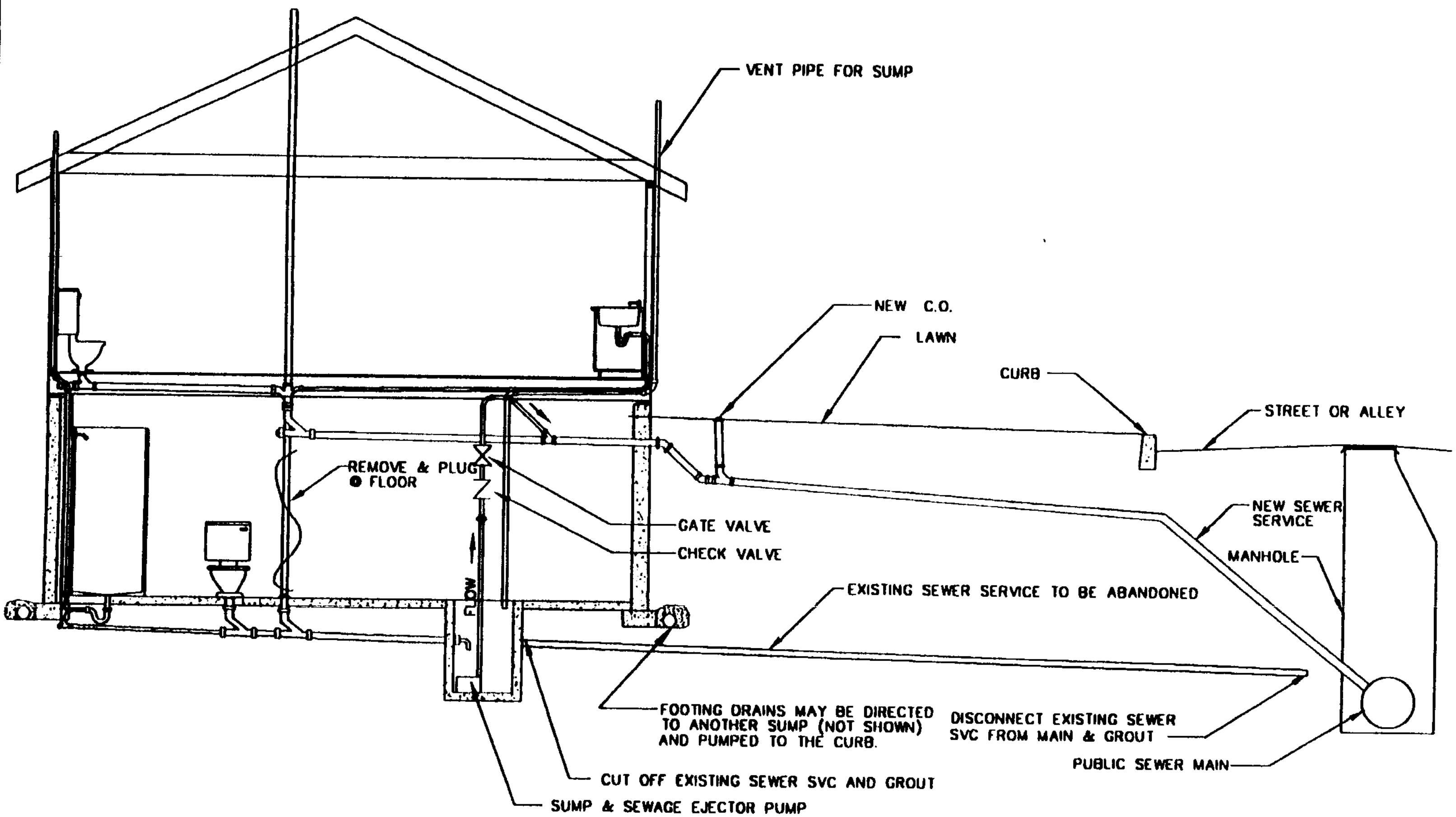

Figure 3

Positive Protection Program

In July 1997, the City Council adopted the Positive Protection Program (PPP) as a strategy for partnering with homeowners to eliminate basement flooding. Some of the features of this program include:

- The home must be located within a study area, have a basement, and experienced flooding due to sanitary sewer backups.
- The City provides technical assistance to the homeowner and a zero interest deferred payment loan (DPL) to fund improvements similar to Alternatives C or D.
- There are no income requirements to be eligible for a deferred payment loan.
- The homeowner is encouraged to receive bids from at least two contractors to do the work. The owner is not required to accept the lowest bid, however the selected bid is reviewed by City staff and must be reasonable.
- Repayment of the deferred payment loan is not required until the property is transferred.
- To be consistent with the City's existing R/R program, the cost of a new sewer service lateral for the home, if required, is funded at public expense.
- Footing drains, when encountered, are diverted to a separate sump and pumped to the curb. Cost for this portion of the project are included in the DPL.

CONCLUSIONS

Over 100 homeowners are currently participating in the City's Positive Protection Program. To date 39 improvement projects have been successfully completed at a total cost of approximately $405,000. Alternative D has been selected the most often by area residents. This may be due to the fact that the majority of the participants in the program consider their basements as a portion of the home's living area and not simply for storage.

The alternatives developed as a result of the City's investigation are believed to be a successful means of eliminating basement flooding in older homes caused by sanitary sewer backups. The program has also been successful in partnering with the community in finding a solution to an ongoing problem.

The Salem City Council is currently reviewing the Positive Protection Program. It is anticipated that some changes in funding for the program may occur in future years.

OAKLAND RAVINE STORMWATER TREATMENT SYSTEM PROJECT BOROUGH OF QUEENS, NYC

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ABSTRACT

Compared to other cities, New York City (NYC) is abundantly endowed with parklands and open spaces, many of which can be utilized to treat and dissipate stormwater runoff flows, in conjunction with the preservation, restoration and creation of ecological systems. Such use of available parklands and open spaces has the benefit of decreasing costs for stormwater treatment and conveyance, while at the same time enhancing the natural biological systems. Through the combined efforts of the NYC Department of Environmental Protection (NYCDEP), which is responsible for stormwater control, and the NYC Department of Parks and Recreation (NYCDPR), which is responsible for preserving and restoring the ecological systems of parklands and open spaces, URS Greiner, Inc. (URSG) developed a project to provide for the treatment of stormwater and the attenuation of peak stormwater flows through restoration and creation of wetlands within Oakland Ravine (located in the densely populated northeastern section of the Borough of Queens, NYC). The proposed Oakland Ravine Stormwater Treatment System Project was developed in conjunction with the East River Combined Sewer Overflow (CSO) Abatement Project, which is part of the NYC comprehensive program to reduce CSO discharges into receiving waters. Discharges into Alley Creek through Outfall TI-7, an outfall located about one-half mile northeast of the ravine which has been designated for CSO abatement, will be reduced as a result of the proposed stormwater treatment system project. The principal objectives of the project are to reduce discharges into Alley Creek, address stresses and disturbances identified within Oakland Ravine and Oakland Lake (located at the north end of the ravine) with regard to erosion and lack of vegetation on the slopes of the ravine and deterioration of the water quality in the lake, reduce/eliminate sewer system flooding in areas adjacent to the ravine and lake, and create a natural park setting in an urbanized area. These project objectives will be met by re-routing stormwater from adjacent sewer systems into the upper (south) end of the ravine and providing primary and secondary treatment of the stormwater within sediment pools and created/restored wetlands, prior to the water being discharged into Oakland Lake, and ultimately into Alley Creek. The project will also include stabilization and planting of the slopes of the ravine with vegetation and trees native to the area, and construction of access trails through the ravine, including bridges over the wetlands, for use by persons walking and riding bicycles.

KEYWORDS

stormwater, wetlands, treatment, ravine, lake

INTRODUCTION

Oakland Ravine, which is part of a City-owned park, is situated in the densely populated northeastern section of the Borough of Queens, NYC. The park also includes Oakland Lake, located immediately north of the

R0025177

ravine. Figure 1 shows the location of Oakland Ravine and Lake within the Borough of Queens. The park, which is surrounded by residential development and educational facilities, serves as an important open space for local residents to engage in such recreational activities as walking, fishing and interacting with the waterfowl which frequent the lake. The ravine is undeveloped and generally consists of trees, scrub plants and wetlands. The slopes of the ravine are steep (ranging from 30 to 60%) and heavily eroded in several areas due to overland stormwater runoff flow from the Queensborough Community College campus which borders the ravine to the east, and from Springfield Boulevard located along the ravine's western boundary as shown on Figure 2. In addition, the portion of the ravine located in proximity to 56th Avenue, which extends along its southern boundary, contains fill material and some debris.

As a result of past studies and investigations relating to the effects of CSO discharges into Alley Creek and to the general degradation of Oakland Ravine and Lake, problems have been identified that need to be addressed to allow the area to be environmentally rehabilitated. In a draft report entitled "Stormwater Treatment and Environmental Quality in Oakland Ravine," prepared in 1993, The Gaia Institute indicated that Oakland Ravine and Lake are ecological systems with impaired functions. Specifically, the report identified a number of stresses and disturbances within Oakland Ravine and Lake, which have resulted in a reduction in biological diversity and loss of native ecological communities capable of purifying incoming water and modulating temperatures. These stresses and disturbances could be reversed by re-routing stormwater from the existing stormwater sewer systems into the ravine. The principal problems identified that need to be addressed from an environmental perspective are as follows:

- Reduced water quality in Oakland Lake and Alley Creek, which have resulted in seasonal anoxic events in the lake.
- High CSO peak flows into Alley Creek through Outfall TI-7.
- Sewer system flooding along 56th Avenue and Springfield Boulevard.
- Erosion and lack of vegetative growth on the ravine slopes.
- Reduction in the amount of water available within the ravine to support native ecosystems as a result of alteration of the surrounding area due to development.
- Sediment buildup in Oakland Lake.

Through the combined efforts of the NYCDEP, NYCDPR and URSG, a project was developed to address the above-listed problems through the re-routing of stormwater into the ravine, and the restoration and creation of wetlands within the ravine to treat the stormwater. The proposed project, referred to as the Oakland Ravine Stormwater Treatment System Project, was developed in conjunction with the East River CSO Abatement Project which includes abatement of CSO discharges into Alley Creek through Outfall TI-7 as shown on Figures 1 and 2.

The principal objectives of the proposed stormwater treatment system project are to address the six (6) problems identified above. An additional objective of the project is to provide enhancements to a City-owned park located in an urbanized area for the use and enjoyment of the local residents and visitors.

EXISTING SEWER SYSTEM

Re-routing of stormwater into Oakland Ravine from the existing sewer systems is a critical feature necessary to meet the objectives of this proposed stormwater treatment system project. As indicated by the existing sewer system schematic presented on Figure 2, the sewers located in proximity to Oakland Ravine and Lake consist of those that convey strictly stormwater (storm sewer) as well as sewers that convey a combination of sanitary sewage and stormwater (combined sewer). During storm events, the combined sewage is conveyed through the combined sewers and discharged into Alley Creek through Outfall TI-7 at peak flow rates as high as 499,620 cubic meters per day (m^3/d) (132 million gallons per day [mgd]). In addition to the sewage from the tributary sewers, the overflow from Oakland Lake is discharged into Alley Creek through Outfall TI-7 as shown on Figure 2 for the purpose of maintaining an ecological balance within the creek.

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PRINCIPAL WATER SOURCES

The sources of stormwater identified for re-routing into Oakland Ravine to supply the water necessary for implementation of the project consist of the following:

- Flow from the storm sewer located in 56th Avenue.
- Runoff from the Queensborough Community College campus.
- Runoff from the areas in the vicinity of Springfield Boulevard.

The storm sewer located in 56th Avenue, which varies in diameter from 530 to 1,500 millimeters (21 to 60 inches), extends westerly from Cloverdale Boulevard to Springfield Boulevard. The drainage area served by this storm sewer consists of approximately 24.7 hectares (61 acres) of which about one-third is located within the boundaries of the Queensborough Community College campus, and the remaining two-thirds encompasses the predominantly high density residential area located south of 56th Avenue. The area of the college campus, which is not included in the drainage area of the storm sewer located in 56th Avenue, consists of about 6.1 hectares (15 acres). Therefore, the total drainage area available for generating stormwater runoff for re-routing into Oakland Ravine from the storm sewer located in 56th Avenue and the Queensborough Community College campus is approximately 30.8 hectares (76 acres).

A large combined sewer located in Springfield Boulevard along the west side of Oakland Ravine conveys sanitary sewage and stormwater from predominantly residential areas south of 56th Avenue and west of Springfield Boulevard. This sewer discharges into the combined sewer located in 46th Avenue. The stormwater runoff generated within this drainage area is the third principal source of stormwater for re-routing into Oakland Ravine.

The projections of the flow volumes and pollutant loadings anticipated to be discharged into the proposed stormwater treatment system from the storm sewer in 56th Avenue and the storm sewer system located on the Queensborough Community College campus were determined. A combination of manual drainage calculations and modeling of the storm sewer systems utilizing the RUNOFF Block of the United States Environmental Protection Agency Stormwater Management Model were used to develop the projections. Rainfall quantities measured in the local area, and measurements of flows and pollutant concentrations within the storm sewer in 56th Avenue during six (6) storm events (three in 1997 and one each in 1990, 1992 and 1993) were used to develop the model. The projections of the annual flow volume and quantities of pollutants anticipated to be discharged into Oakland Ravine through re-routing of the stormwater from the storm sewer in 56th Avenue and the Queensborough Community College campus for a year with an average rainfall of approximately 1,092 millimeters (43 inches) (based on measured rainfall at LaGuardia Airport for the period of 1948 through 1995) are presented below in Table 1:

Table 1: Average Annual Projections of Flow and Pollutant Loadings

Flow Volume: 189,270 cubic meters (50 million gallons)

Pollutant Loadings: kilograms (kg)

- Biochemical Oxygen Demand (BOD_5): 1,565 kg (3,450 pounds)
- Ammonia (NH_3): 45 kg (100 pounds)
- Nitrate (NO_3): 132 kg (290 pounds)
- Total Kjeldahl Nitrogen (TKN): 36 kg (80 pounds)
- Total Phosphorous (TP): 54 kg (120 pounds)
- Total Suspended Solids (TSS): 2,885 kg (6,360 pounds)

The projected annual pollutant loadings presented in Table 1 are relatively low. Therefore, such results provide confidence that the wastewater being conveyed within the storm sewer in 56th Avenue and from the college's stormwater collection system consists predominantly of stormwater. The investigation to determine similar flow and loading projections for the stormwater runoff from the areas adjacent to Springfield Boulevard are still underway.

EXISTING HABITAT CHARACTERISTICS

A major consideration in development of the proposed Oakland Ravine Stormwater Treatment System was to maintain and enhance the native characteristics (tree species, plant and animal habitats, lake water quality, etc.) of the ravine and lake to the greatest extent possible. Extensive evaluations and assessments of the ravine and lake were conducted to establish and identify the native characteristics for use in development of the proposed stormwater treatment system. Following is a summary of the principal results of these evaluations and assessments:

- Approximately 300 trees with trunks larger than 150 millimeters (6 inches) in diameter as measured at about 1.4 meters (4.5 feet) above the ground were identified as to species and their locations were documented; the ravine slopes are generally dominated by large oaks with occasional large hickories, beeches and tulip trees, and with smaller hickories, black cherries, birches and maples located in the understory.
- A total of twenty-two different species of birds were observed within the ravine and lake, and healthy populations of sunfish, bluegill, white crappie, bass, large carp and goldfish were observed in the lake.
- Anoxic conditions were observed in most areas of the lake near the bottom with anoxic/hypoxic conditions extending to within 4 feet of the water surface.
- Nutrients in the lake water were relatively low; phosphate levels were below 0.05 milligrams per liter (mg/l) at all times, and nitrate levels were below 0.25 mg/l during warm weather and rose to slightly more than 1.0 mg/l in colder weather.
- Macrophyte coverage of the lake was observed to be extensive with *Potamogeton crispum* being predominant in early summer and by mid-summer being replaced by *Cabomba caroliniese*.
- One (1) wetland area was identified in the ravine encompassing an area of 0.57 hectare (1.4 acres) consisting primarily of palustrine persistent emergent.
- No rare, threatened or endangered species were identified.

DESCRIPTION OF STORMWATER TREATMENT SYSTEM

Based on the information and data obtained from evaluations and assessments of the ravine and lake, investigations of the sewer systems in the vicinity of the ravine and lake, discussions with individuals who possess specific knowledge of the local area, and literature searches, a conceptual plan for the proposed Oakland Ravine Stormwater Treatment System was developed. This conceptual plan was developed to meet the project objectives, thereby addressing the identified problems, as previously discussed, with stormwater being re-routed into the ravine from the three (3) principal sources. The conceptual plan of the proposed stormwater treatment system is presented on Figure 3 and illustrative sections of the plan are presented on Figure 4.

The major components which make up the proposed stormwater treatment system are as follows:

- Re-routing of stormwater from the storm sewer in 56th Avenue, the Queensborough Community College campus and areas adjacent to Springfield Boulevard into the ravine.
- Plunge pools with rock cascades for energy dissipation.
- Rock check dams with naturalized rock channels for velocity reduction and habitat enhancement.
- Pools for collection of sediment, floatables and debris.
- Restoration/creation of wetlands to treat stormwater.
- Stabilization and planting of ravine slopes.
- Trails and signage throughout the ravine with bridges extending over wetlands to create a park setting.

The measures included in the conceptual plan of the proposed stormwater treatment system for re-routing the stormwater into the ravine from the storm sewer in 56th Avenue and the Queensborough Community College campus are shown on Figures 3 and 4. Stormwater from the storm sewer in 56th Avenue will be re-routed into the ravine by disconnecting the 1,500-millimeter (60-inch) diameter storm sewer from the combined sewer located in Springfield Boulevard, constructing a diversion chamber within 56th Avenue at a location approximately 115 meters (380 feet) east of Springfield Boulevard, and extending a 1,500-millimeter (60-inch) diameter storm sewer in a northerly direction from the diversion chamber into the ravine where the stormwater flow will be freely discharged into the upper plunge pool. Stormwater runoff from the Queensborough Community College campus stormwater collection system will be re-routed to a stormwater collection system constructed along the tops of the eastern slopes of the ravine as shown on Figures 3 and 4. This proposed stormwater collection system consists of an underground 1,500-millimeter (60-inch) diameter collection/detention pipe with holes through the walls to allow the water to percolate into the eastern slopes of the ravine in a controlled manner. The collection/detention pipe will be installed in a rock-filled trench to enhance the percolation of the water into the soil and to provide increased storage volume. Percolation of the water into the slopes of the ravine is important to sustain vegetative growth. Although re-routing of stormwater runoff from areas adjacent to Springfield Boulevard is a component of the proposed stormwater treatment system, the method of how this re-routing of flows will be accomplished, is still under investigation, and as such, the facilities required to re-route these flows are not shown on Figures 3 and 4. However, it appears that a stormwater collection system installed along the tops of the western slopes of the ravine, similar to that proposed for the eastern slopes, to allow a controlled percolation of water into the slopes may be the preferred method.

As shown on Figure 3, the proposed stormwater treatment system is separated into four (4) zones; identified as Upland Cascades, Rock Riffles, Wetland Forebay and Emergent Marsh. The principal features and benefits pertaining to each of these zones are summarized as follows:

- Upland Cascades
    - 1,500-millimeter (60-inch) diameter pipe discharging stormwater from the storm sewer in 56th Avenue.
    - Series of three (3) plunge pools with gabion mattresses or natural rock bottoms and rock cascades to dissipate energy for a 6.1-meter (20-foot) drop.
    - Aeration of stormwater by rock cascades.
    - Access trail from 56th Avenue.
    - Stabilization and re-vegetation of area.
- Rock Riffles
    - Series of four (4) rock check dams with rock channels to further dissipate velocity.
    - Aeration of stormwater with rock cascade having a vertical drop of about 2.4 meters (8-feet).
    - Access trail.
    - Stabilization and re-vegetation of slopes.
- Wetland Forebay
    - Further dissipation of velocity.
    - Retention and collection of floatables, oil, grease, debris and settleable solids in pools.
    - Primary treatment of stormwater within pools and wetland fringe having a combined area of about 0.53 hectare (1.3 acres).
    - Earth berm with control structure and discharge conduit designed to discharge stormwater into the Emergent Marsh Zone while preventing the passage of floatables, oil, grease, solids and debris.
    - Emergency rock channel spillway to pass high flows caused by large storms (greater than the 25-year storm).
    - Access trails with bridges.
    - Stabilization and re-vegetation of slopes.
- Emergent Marsh
    - Secondary treatment of stormwater within an emergent wetland having an area of about 0.49 hectare (1.2 acres) through pollutant breakdown by bacterial action and nutrient uptake by plants.
    - Hydraulic connection to lake.
    - Access trails with bridge.
    - Stabilization and re-vegetation of slopes.

The proposed Oakland Ravine Stormwater Treatment System provides both physical and biological processes for pollutant removal from the stormwater. Physical treatment processes include flow moderation, settling of solids, filtration and adsorption. Biological treatment processes include pollutant breakdown by bacterial action and nutrient uptake by plants. The Wetland Forebay Zone will be designed to efficiently trap floatables, oil, grease, debris and settleable solids to protect the downstream Emergent Marsh Zone. Within the Emergent Marsh Zone, pollutant removal will take place as a result of the biological processes. A circuitous flow path will be provided through the Emergent Marsh Zone to increase contact time between the water and the plants to enhance the biological treatment.

Based on the performance results of wetlands being used to treat stormwater, it is anticipated that the proposed Oakland Ravine Stormwater Treatment System will reduce the levels of total suspended solids in the stormwater by about 50 to 75%, total phosphorous by 45%, total nitrogen by 25% and organic carbon by 15% with some reduction in metals. These reductions in the pollutant levels will have a significant impact on the quality of water in Oakland Lake with a lesser impact on the water quality in Alley Creek. However, the proposed stormwater treatment system will have a significant impact on Alley Creek by attenuating the CSO peak flow discharges through re-routing of stormwater through the ravine and lake.

The estimated cost to construct the proposed stormwater treatment system, excluding facilities to re-route stormwater into the ravine from areas adjacent to Springfield Boulevard, is approximately $5,000,000. Construction of the project is anticipated to be completed in the year 2001.

CONCLUSIONS

In conjunction with the NYC East River CSO Abatement Project, a project has been developed to provide for the treatment of stormwater in Oakland Ravine, located within the densely populated northeastern section of the Borough of Queens, NYC. Stormwater, which will be re-routed into the ravine from adjacent sewer systems, will receive primary and secondary treatment within a naturalized treatment system consisting of water pools, rock cascades and created/restored wetlands. The project will address the following identified problems pertaining to the environmental quality of the area:

- Reduced water quality in Oakland Lake and Alley Creek.
- High CSO peak flows into Alley Creek through Outfall TI-7.
- Sewer system flooding along 56th Avenue and Springfield Boulevard.
- Erosion and lack of vegetative growth on the ravine slopes.
- Reduction in the amount of water available within the ravine to support native ecosystems.
- Sediment buildup in the lake.

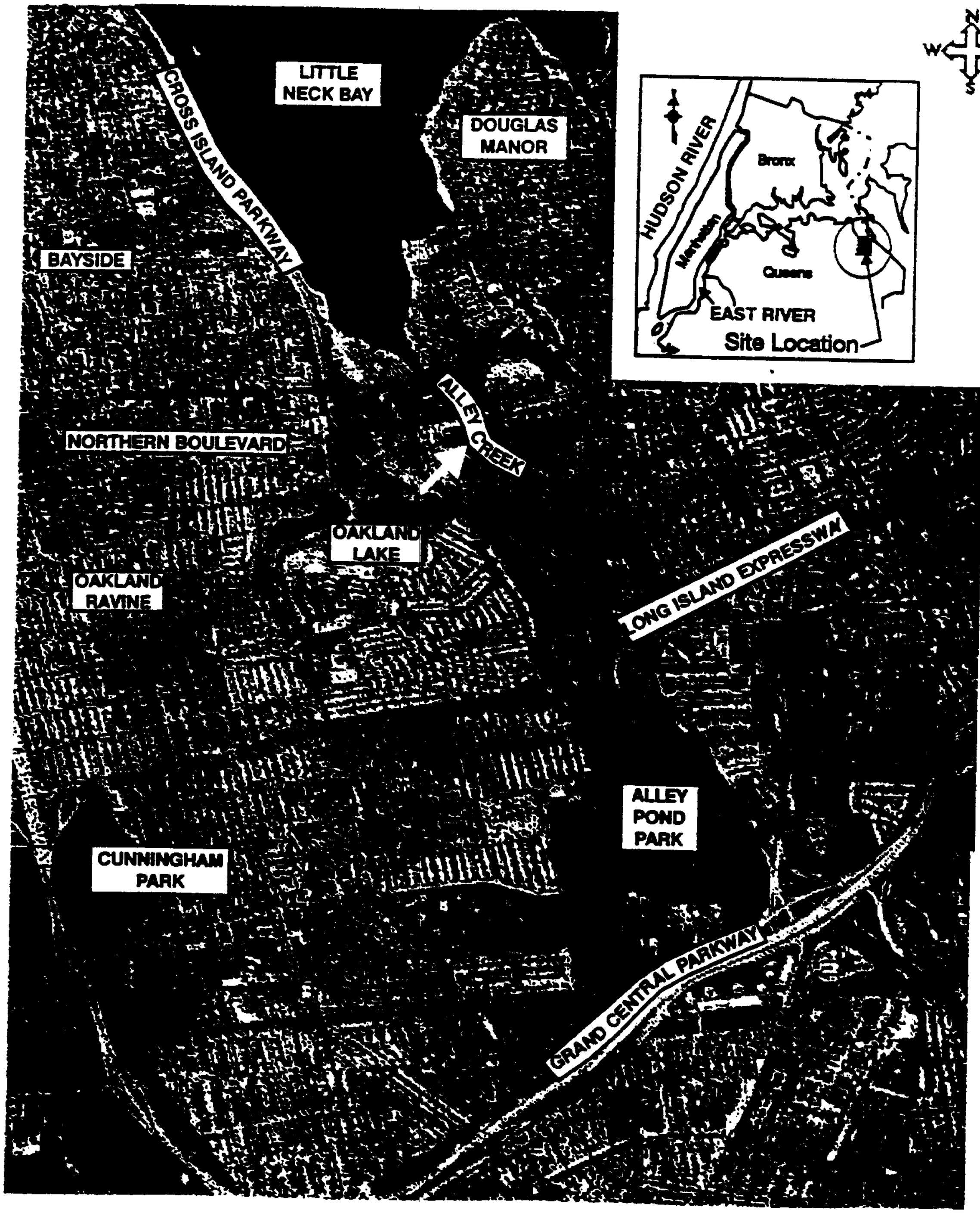
In addition to providing solutions for the identified problems, the project will provide enhancements to a City-owned park located in an urbanized area.

ACKNOWLEDGMENT

The authors wish to thank the many representatives of the NYCDEP and NYCDPR as well as other interested private citizens and groups, who provided valuable input and assistance in the development of the Oakland Ravine Stormwater Treatment System Project.

REFERENCE

The Gaia Institute (1993) draft report "Stormwater Treatment and Environmental Quality in Oakland Ravine".



LEGEND

OUTFALL TI-7

LOCATION PLAN	FIGURE 1

FullmapB.cdr-sy71

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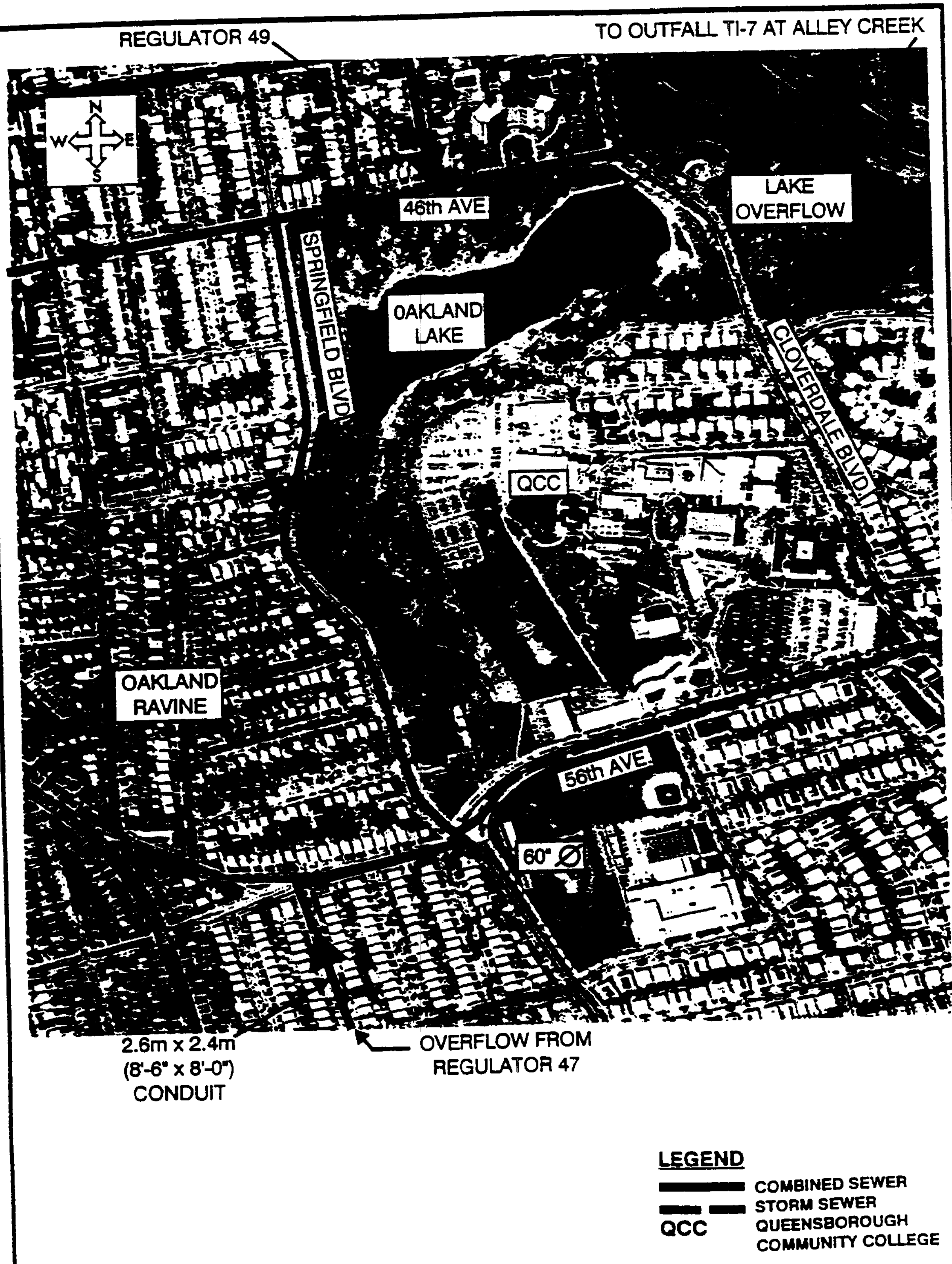

SEWER SYSTEM SCHEMATIC | FIGURE 2

FULLMAP3 CDR-SY71

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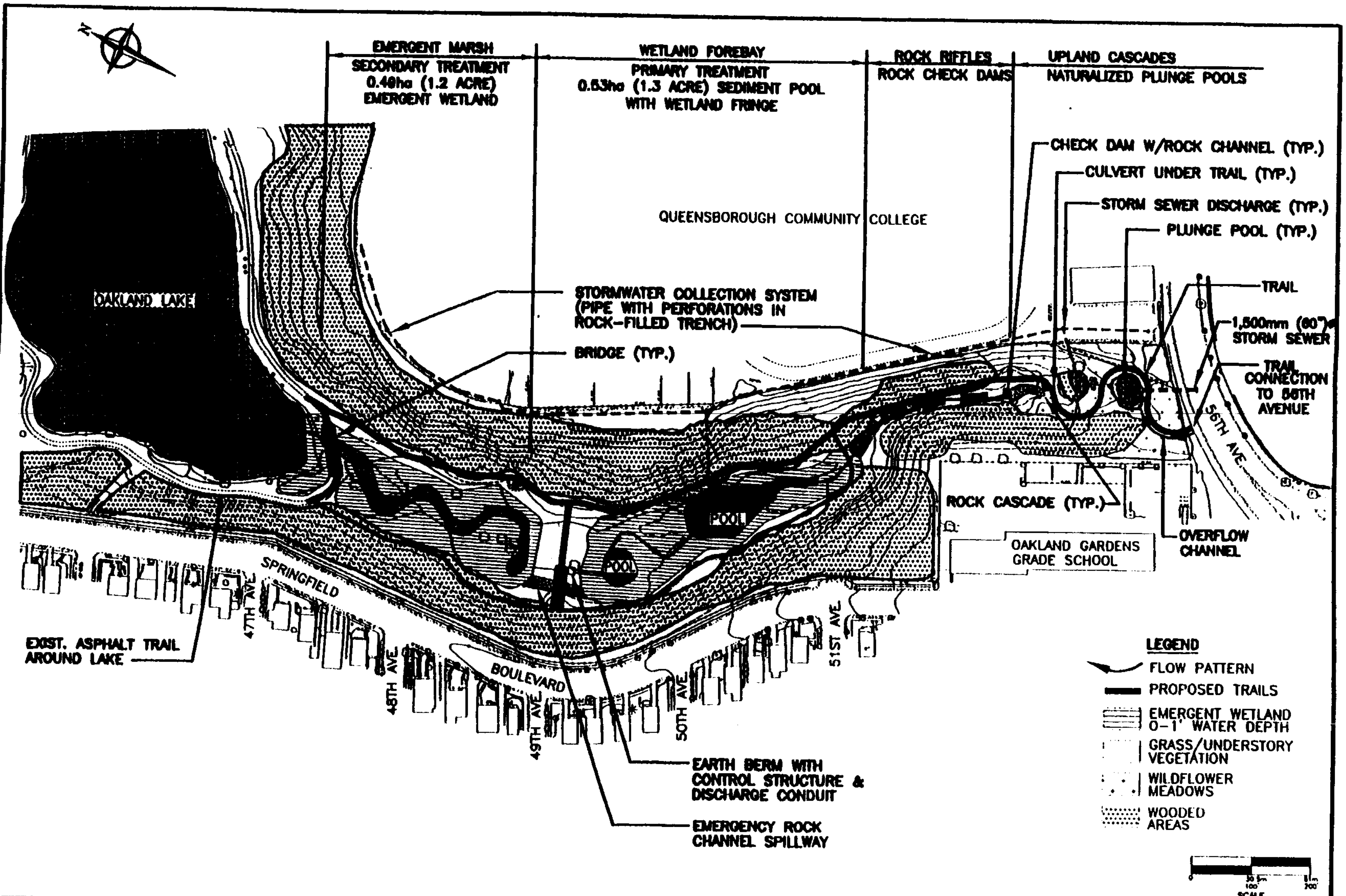
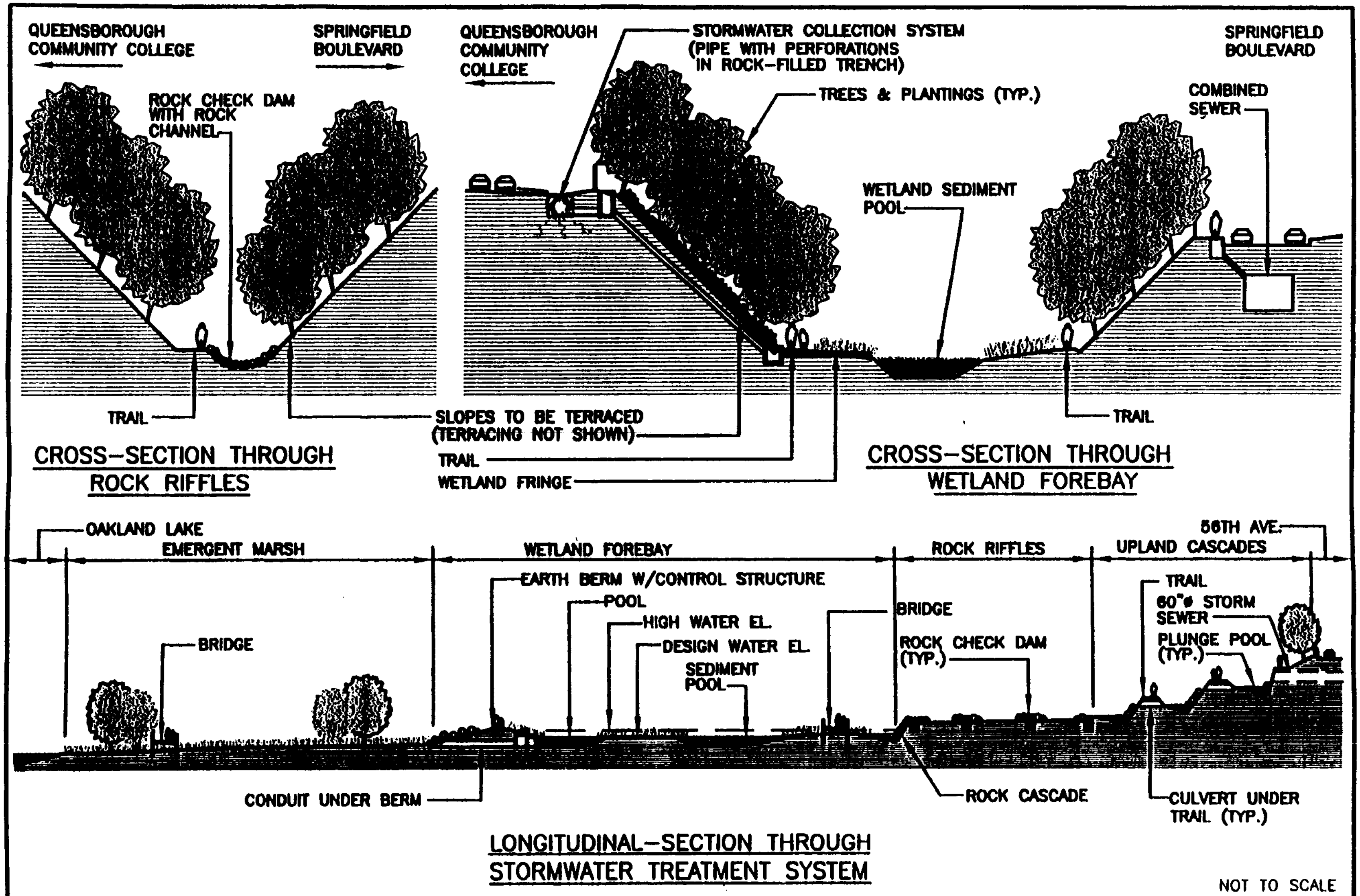


STORMWATER TREATMENT SYSTEM CONCEPTUAL PLAN

FIGURE 3



STORMWATER TREATMENT SYSTEM ILLUSTRATIVE SECTIONS

FIGURE 4

TULSA ADDRESSES SANITARY SEWER OVERFLOWS

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ABSTRACT

An Administrative Order issued by Region VI of the U.S. EPA and a Consent Order entered into with the Oklahoma Department of Environmental Quality require the Tulsa Metropolitan Utility Authority (TMUA) to report overflows and complete projects to eliminate overflows and bypasses on a specified schedule. This paper describes data collection and computer modeling to identify and correct deficiencies in a group of sub-basins tributary to one treatment plant. The project required evaluation of over 300 km of 150 mm through 1,500 mm gravity sewer, approximately 5,300 manhole structures, several inverted siphon crossings of area drainage courses, and a dual barrel crossing of the Arkansas River to the plant influent pump station. A computer model of the major (typically 250 mm and larger) gravity lines was used to evaluate the system's ability to pass the design storm flow.

TMUA operates several long-term flow meters, six of which provided flow data for this project. 27 additional area velocity temporary flow meters and 6 rain gauges were installed to subdivide drainage basins into reasonable tributary areas. Dry and wet weather flow data were collected and analyzed to establish flow patterns and calibrate the model. Data from four of the six long-term sites were determined to be usable, but inconsistencies in data from the other two sites prevented their use.

Flow data confirmed that no capacity problems exist under normal conditions, but capacity is frequently exceeded during wet weather. Peak dry weather flows ranged from a low of 5.7% to a high of 64.5% of nominal capacity while peak wet weather flows ranged from a low of 20.9% to a high of 272.3%. Evaluation of data established that the predominant problem is inflow, with some 63% originating in six tributary basins outside of the study area. Four sub-basins contribute in excess of 50% of the inflow attributable to sources within the study area. Computer modeling of the system further defined the extent of capacity problems within the project area and confirmed necessary corrective actions to eliminate overflows.

Approximately 97% of the manholes were inspected for inflow contributing defects. The remaining 3% were inaccessible. All lines were smoke tested and CCTV inspection in conjunction with dye testing of suspected inflow sources was completed for selected line segments. A dynamic computer model, capable of accurately modeling open channel, surcharged and restricted flow, was used to simulate existing system response and project response following rehabilitation.

KEYWORDS

Inspection, monitoring, modeling, rehabilitation, SSO, testing.

INTRODUCTION

The sanitary sewer collection system tributary to Tulsa's Southside Wastewater Treatment Plant is subject to large increases in flow during rainfall and snowmelt events. The entry of extraneous wet weather flow into the system has frequently resulted in overflows from surcharged manholes, backups in low-lying structures, and bypasses into the Arkansas River and its tributary creeks which pass through the metropolitan area. The TMUA has been addressing the extraneous flow problems in its entire wastewater system for the past several years through a number of flow monitoring studies, sewer system evaluations, relief sewer construction programs, and rehabilitation of existing lines and manholes. Both the United States Environmental Protection Agency (USEPA) and the Oklahoma Department of Environmental Quality (DEQ) have issued enforcement orders to reduce the frequency and duration of overflows and bypasses from the sewer system.

The sewer subsystem described in this paper collects wastewater from the most downstream basins tributary to the Southside Wastewater Treatment Plant and conveys flow originating in upstream basins to the plant. The subsystem includes over 300 km of gravity sewers ranging in size from 150 mm to 1,500 mm in diameter, a crossing of the Arkansas River by twin 900 mm lines, several multiple barrel siphon crossings of area creeks and drainage courses, and approximately 5,300 manholes and lampholes. The specific purpose of the study described in this paper was to determine the extent of the infiltration/inflow (I/I) problem, locate and quantify specific sources of I/I, and establish a cost-effective rehabilitation program to reduce flow in the collector and interceptor sewers so that no bypasses or overflows would occur during any wet weather event up to and including the five (5) year design storm.

Significant lengths of sewer line in the project area have been in service for more than 50 years and display the typical signs of aging expected in sewers of that vintage. Vitrified clay pipe (VCP) and concrete pipe (RCP) are the predominant materials of construction for these sewers. Cast iron pipe (CIP) or ductile iron pipe (DIP) have been used to a limited extent, primarily where the lines cross beneath small creeks and other surface drainage features.

METHODOLOGY

A total of 27 temporary flow meters would be installed for a period of 45 days at the beginning of the study to measure flow within the system at key points. Data collected would be supplemented with data from six (6) TMUA-owned long term meters installed in several of the major interceptors. Six (6) automatic tipping bucket rain gauges would be installed at selected locations across the study area to provide rainfall data for correlation with the flow data. Analysis of the flow and rain data would permit identification of specific areas where wet weather appears to most heavily impact the system under study. The data also would be used to calibrate the computer model and confirm that it represented the sewer system and its response to wet weather events with reasonable accuracy.

A visual inspection of the sewer system would be conducted to determine the condition of the manholes and segments of connecting pipe visible from the manholes. Smoke testing would be conducted on the entire system (with minor exceptions) to locate defects such as suspected cross connections between the storm and sanitary sewers, area drain connections, defective manhole frames, covers and seals, and pipe defects which could admit ground water into the system. Following the visual inspection and smoke testing, suspect areas would be inspected by use of closed circuit television cameras in conjunction with dyed water flooding of suspected sources of extraneous flow, to confirm the type, location and severity of the suspected defects. In addition to location of defects, the inspection methods would be used to confirm manhole and line sizes, depths, and connectivity to permit accurate system modeling and updating of existing collection system maps. Field surveys would be conducted to provide correct elevations at manholes where data were not available from record drawings or previous modeling activities.

Data collected through the various inspection methods would be analyzed to categorize defects by priority and anticipated method of rehabilitation. In addition to defects contributing to I/I, defects potentially affecting the structural integrity of the sewer system would be evaluated and their correction prioritized. Defects posing an immediate hazard would be reported to TMUA staff for prompt attention. Likewise, any defects noted on private property would be reported to TMUA staff for resolution with the property owner(s). Data would be collected and entered into a database for ease of manipulation and analysis. Photographic documentation of defects would be digitally recorded for ease of reference and recovery.

The major interceptor lines, and smaller collector lines in which temporary flow monitors were installed, would be defined in a computer model which would be calibrated from the monitored flow data and tributary area land use and population. The calibrated model would then be used to determine the expected effectiveness in eliminating overflows and bypasses from completion of the recommended rehabilitation measures. The modeling results would indicate to what extent correction of defects within the study area,

DISCUSSION

The Southside Plant Influent Sewer System Evaluation Survey is but one of a number of investigations undertaken by the TMUA in response to wet weather conveyance problems in TMUA's service area. The overall correction program has been underway for a number of years, and has involved the efforts of many consultants as well as Tulsa Department of Public Works (DPW) staff. The City of Tulsa recently celebrated its 100th anniversary, and some of the sewer lines serving the city are approaching their centennial anniversary as well. Tulsa's decision to address problems on a system-wide basis provides a consistent, integrated approach which should yield the most cost-effective long term solutions, while still providing for a quick response to high priority problems.

Flow monitoring

A network of long term flow monitors installed by TMUA, supplemented with temporary flow monitors placed at key locations during each separate area study, permitted prioritization of problem areas for further analysis. In addition to helping identify significant problem areas, the long term monitors provide a means to measure the general effectiveness of rehabilitation work accomplished over the life of the program by providing comparative data throughout its duration. Two separate flow paths exist at two locations within the collection system described in this paper, as can be seen on the flow schematic in **Figure 1**. The use of two additional temporary flow monitors to determine how flow is split between the separate flow paths at each of these locations would have increased the accuracy of the flow analysis for the system. However, since a significant difference in invert elevations exists between the two flow paths at each location, the absence of the additional flow monitors had no effect on dry weather flow measurement. Assumptions were necessary regarding the percentages of flow carried in each line during the wet weather flow analysis.

Flow monitoring data indicated that the monitored sites experienced neither depths of flow greater than 0.7 times pipe diameter nor peak flows in excess of 80% of the nominal full pipe capacity during any of the monitored dry weather periods. Likewise, data indicated that 15 of the monitored sites surcharged (depth of flow exceeded pipe diameter) and 9 sites experienced flow rates in excess of nominal full pipe capacity during at least one wet weather event. Four of the sites that surcharged did not experience flows in excess of full pipe capacity, indicating they were experiencing backwater conditions. **Figure 4** shows a typical wet weather response observed at the temporary monitoring sites, indicating that inflow sources represent a larger SSO problem than do infiltration sources. Inflow is indicated by the immediate response to the heavy rainfall the night of October 20th, followed by a rapid return to slightly elevated flow levels. Infiltration into the system is represented by the more gradual return to pre-storm flow levels following the longer duration but lower intensity rainfall on October 22nd.

Manhole inspections

Approximately 97% of the manholes and lampholes were physically inspected for defects and to confirm depths to pipe inverts and connectivity of the sewer system for modeling purposes. Since a significant portion of the system being investigated was constructed in easements rather than in dedicated public rights-of-way, a limited number of the structures could not be accessed for inspection. Typical reasons included construction of obstructions (fences, decks, outbuildings, etc.) over the recorded location of the structures. It is suspected that a number of structures were buried by subsequent fill or paving operations. The inspections completed were extensive enough to be representative of the entire study area and the absence of smoke escaping from suspected buried manhole locations indicated that I/I admitting defects were unlikely to exist at those uninspected sites.

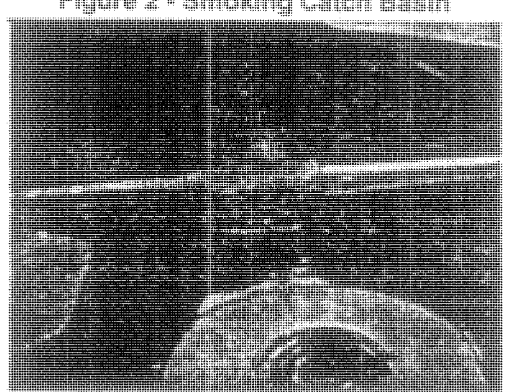
All identified manhole defects were assigned a rehabilitation priority based upon the severity of the defect (or combination of defects in a single manhole). Severities were determined from both personnel safety and I/I volume estimates associated with the defects. A majority of the defects identified were significant enough to warrant either immediate or very near term corrective actions being taken. Significant inflow removal is expected to result from replacement of the large number of vented manhole covers identified by the inspection program and by installation of flexible seals between the frames and the manhole chimneys.

Smoke testing

Over 300 km of main line sewer, and the connecting private service lines, were smoke tested to locate cross connections with the storm sewers in the area, identify I/I entry points in manholes not detectable by visual manhole inspection, locate buried openings in mainlines through which groundwater could enter, and document sources of I/I from defects or illegal connections on private property. Defects indicated by visible smoke were photographically recorded in addition to being noted on inspection forms and graphically depicted in sketches. All smoke testing results were transferred into the inspection database. Photographs were scanned into the recording system to provide a permanent and easily accessible record of the smoke testing results. Prints of the photographs depicting private property defects were provided to the TMUA for follow-up action with the property owners. Suspected cross connections with storm sewer lines were evidenced by smoke escaping from a significant number of catch basins. See **Figure 2** for an example. Little evidence was found of roof drains being connected to the sanitary sewer system.

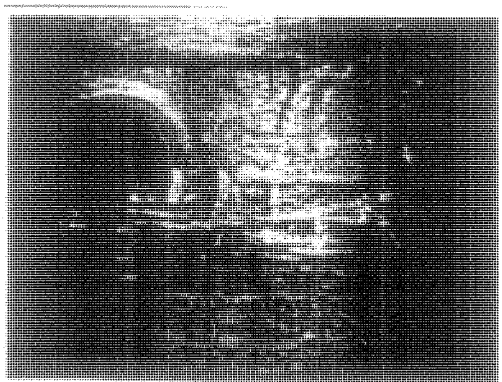
CCTV inspection

Figure 2 - Smoking Catch Basin



All pipe defects identified by smoke testing or during manhole inspections were assigned priority ratings from 1 through 3, with 1 being the highest. All priority 1 pipeline defects were scheduled for inspection by closed circuit television (CCTV) methods. Representative priority 2 defects were also included in the CCTV inspection program. Dyed water flooding of suspected inflow sources was conducted concurrently with the CCTV inspection to confirm that the suspected source was an actual source and to estimate the rate of inflow from the confirmed source. Although a number of catch basins had shown evidence of cross connections to the sanitary sewer during the smoke testing phase, the CCTV inspection was unable to confirm a single direct cross connection. However, a number of indirect cross connections, some with significantly high estimated rates of inflow, were detected. Major problems identified during this phase of the study included sewer lines which appeared to have suffered heavy damage by construction or settlement of other utility lines crossing above the sanitary sewer. **Figure 3** is an example of such damage. In this photograph taken from the recorded video tape, we see a storm sewer line has been constructed across the top of a sanitary sewer line. An entire section of sanitary sewer pipe has been broken out, a void surrounds the remaining portion of the sewer line, and the storm sewer is actively leaking into the sanitary sewer through a defective joint in the storm sewer. Due to the possibility of a surface collapse at this defect, it was reported to TMUA immediately upon discovery for correction.

Figure 3 - Storm/Sanitary Cross Connection



Computer modeling

Close calibration between modeled flows and both dry and wet weather monitored flows was attained. This successful calibration of the model provided confidence in the ability of the model to accurately identify specific problem areas and project the impact of proposed rehabilitation measures. Modeling also permitted evaluation of varying input rates from the multiple influent sources to the Southside Wastewater Treatment Plant during critical flow periods and the impact of the planned diversion of one pumping station flow from the Southside Wastewater Treatment Plant to another treatment facility. It also confirmed that significant efforts must be made to correct I/I source defects on private property for TMUA's program to eliminate overflows and bypasses in the study area to be successful.

including those on private property which would be the responsibility of individual property owners, would result in attaining the required reductions in overflows and bypasses. It would also indicate the extent to which reductions in wet weather flows from upstream basins may be necessary should sufficient reductions not be attainable within the study area basins alone.

RESULTS

Flow monitoring

Of the 33 meters used during the 45 day flow monitoring period, 31 produced results which could be used in analyzing dry and wet weather flow at key points in the sewer system. Two of the long term meters produced data of questionable accuracy during this period. One site experienced erratic velocity readings during the period and the flow data supplied was based upon Manning's equation. The depth at this site was also suspect since the recorded level increased significantly during each rainfall event and, unlike other sites, failed to return to normal values after conclusion of the rain event. The second questionable site recorded levels an average of 2.5 to 10 cm lower than upstream meter sites. Physical examination of this site following receipt and review of the questionable data showed levels approximately 7.5 to 10 cm higher than reported under similar conditions during the monitoring period. **Figure 1** is a flow schematic indicating the relationship between each of the flow monitors in the collection system monitored for this study. Flow monitoring confirmed that no problems with system capacity exist under normal dry weather conditions, but conveyance capacity was exceeded at several monitoring locations during the 45 day monitoring period.

Manhole inspections

5,174 manholes and lampholes were physically inspected for defects which could admit extraneous flow or affect the integrity of the structure. An additional 151 which could not be located in the field, were buried, or were otherwise inaccessible, were not inspected. Included in the 5,174 total were a number of manholes and corresponding line segments which did not appear in TMUA records but were discovered and added to the records during the inspection process. Each manhole that could be opened was inspected, regardless of its condition, and inspection observations were recorded on standard manhole inspection forms for transfer into the appropriate database records. Manhole inspections identified in excess of 5,000 individual defects which warranted attention, either immediately or within the next five (5) years. The most common defect contributing to significant inflow problems within the area studied was vented manhole covers located in areas subject to surface runoff ponding or sheet flow. Manhole inspections also identified potentially significant defects in a number of the sewer lines where they entered the manhole, or within the first few pipe segments visible from the manhole.

Figure 1 - Flow Schematic

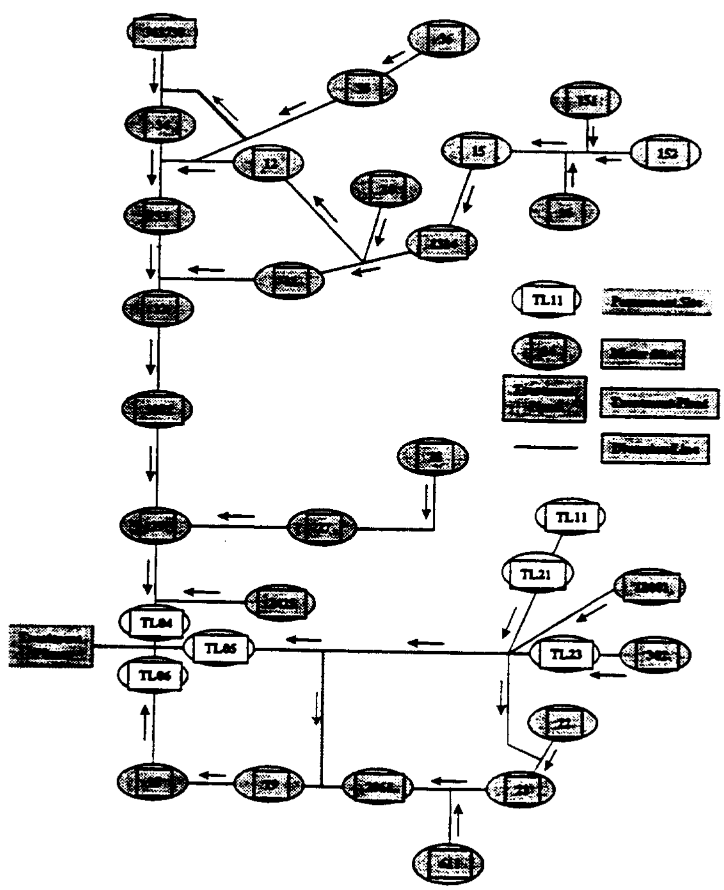


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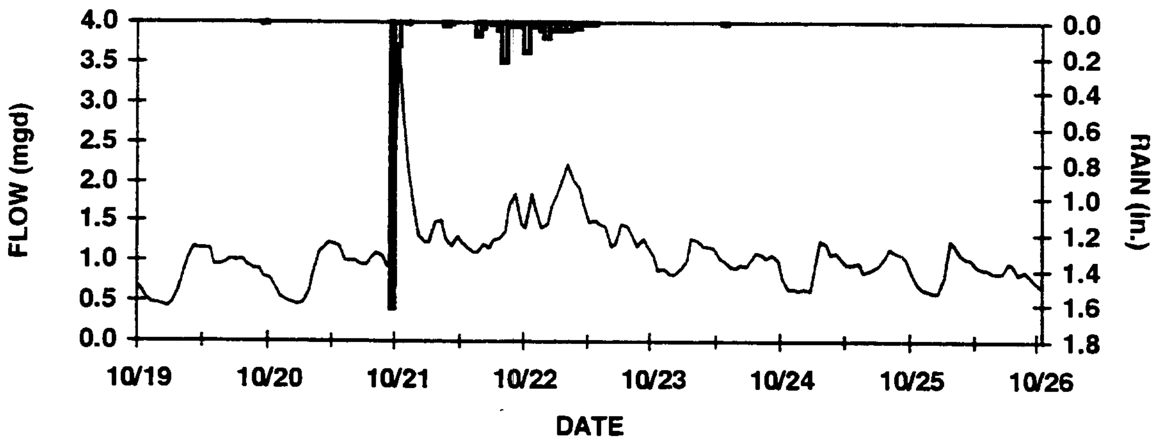
Figure 4 - Typical Wet Weather Response



All manhole inspection data were entered on standard manhole inspection forms for subsequent scanning into the manhole database. Standard entry codes were used to minimize errors in input and scanning or misinterpretation of entries during subsequent analysis of the data. Provisions were made at the outset to identify new structures which were not included in the original TMUA database or did not appear on the sewer atlas sheets. Standard numbering of manholes and consistent references were maintained throughout the inspection and analysis activities.

Standard forms and codes were also used for entering pipe inspection data conducted concurrently with the manhole inspections. Adhering to the standardized numbering system for identification of line segments minimized errors in assigning inspection results to the correct line segments. Standardization also provided consistency in reporting among the different crews used to perform the inspections.

Smoke testing

Smoke testing was conducted throughout the study area, with the exception of the sewer lines immediately adjacent to a large hospital and its corresponding medical complex. All of the facilities connected to the lines near the hospital which were not smoke tested were included in the building inspection program for detection of significant I/I sources. Smoke testing located a large number of defects on private property, including major I/I sources such as area drains. Roof drain connections to the sanitary sewer system do not appear to be a significant source of inflow within the study area.

Data from smoke testing were also recorded using standard defect codes on standard forms for scanning into the database. In addition to photographic documentation of defects evidenced by smoke escaping from the lines under test, sketches showing the location of each defect relative to known features were made. Photographs and sketches were converted into computer files with links to the specific defects. Electronic recording of the data and supporting documentation will permit easy access for review and follow-up by TMUA personnel as the program progresses. Smoke testing results became a primary source for selection of specific lines to be inspected by CCTV.

CCTV inspection

Approximately 5% of the total length of sewer lines were selected for CCTV inspection to confirm suspected defects identified by pipe inspections or smoke testing. Highest priority was given to investigating possible cross connections to the storm sewer system due to the potential for extremely high inflow rates through

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such connections. Although smoke was seen to escape from a number of storm sewer inlets, only one direct cross connection was detected through CCTV inspection. In this particular instance, what appears to be a short relief line was constructed between the storm and sanitary sewer systems in such a manner that it could operate as a relief line in either direction, depending upon the flow level in the respective sewers. Other cross connections appear to be of the indirect type, where the two systems either cross or are within close proximity to each other, and both systems have defects which permit exchange of flow.

All CCTV inspections were conducted with color cameras equipped with movable heads to permit examination of service connections to the main line and the first few sections of pipe in the service lines themselves. Dyed water flooding was performed in conjunction with CCTV inspection of many suspect line segments. Positive detection of dyed water entering the sewer system was recorded for over 90% of the suspected sources tested in this manner. Although some sources showed I/I rates that were barely more than slow seepage, rates exceeding several liters per minute were estimated at a significant number of the positive locations. Some major I/I sources confirmed by this method were heavy leakage from flooded storm sewers through significant defects in the sanitary sewer lines (broken or shattered pipe, open or broken joints, holes in the pipe, etc.) and defective service connections in the vicinity of sink holes visible on the surface. Several significant structural defects were noted (collapsed pipe sections, shattered pipe sections, circular and longitudinal cracks, etc.) which did not demonstrate active I/I at the time of the CCTV inspection and were not adjacent to dyed water tested segments, but may well serve as I/I entry points.

A large number of the VCP lines showed evidence of root penetration through nearly every pipe joint. This problem was not unexpected considering the age of the lines and the extensive usage of side and rear yard easements for construction of the sewer lines. A number of the smaller diameter concrete lines displayed evidence of deterioration from corrosion. CIP and DIP segments displayed varying degrees of deterioration, with none representing structural problems at this time. However, some of the older iron pipe segments have developed interior tuburculation sufficient to create hydraulic restrictions.

Computer modeling

Computer modeling of the study area was intended to serve a number of purposes. First and foremost was to determine whether or not removal of identified I/I sources within the study area would eliminate bypasses from an overflow structure (**Figure 5**) on the east bank of the Arkansas River at the upstream end of the dual pipe river crossing to the South Side Wastewater Treatment Plant. An additional purpose was to identify problem areas which could result in backups or overflows at other locations in the sewer system and the extent of I/I reduction necessary to prevent this from happening. Since a number of the projects completed or underway in sewer basins upstream from the area of this study included provision of relief sewers to alleviate backup and overflow problems, the modeling would also have to project the impact of receiving upstream flows at a faster rate than has previously occurred. TMUA is also planning to divert flow from one pumping station which currently discharges into the Southside Plant system into another of their treatment facilities. The modeling addresses the effect of this flow reversal on the collection system in the study area and upon the treatment plant flow.

Figure 5- Overflow Gate

Modeling of the collection system, the river crossing, and the Southside Plant influent pump station confirms that adequate dry weather capacity is available to convey all tributary flows without bypassing or overflowing from the system unless an unexpected blockage occurs. It also confirms that correction of I/I sources, both public and private, identified in the study area are necessary to prevent regular overflows during extreme wet weather conditions.

CONCLUSIONS

One major conclusion can be drawn from the results of the study reported in this paper. The TMUA can effectively reduce the frequency and volume of bypasses from the Southside Plant Influent Sanitary Sewer System by continuing the program of evaluation and rehabilitation they initiated several years ago. The investigations conducted and recommendations resulting from this study, when completed, will reduce wet weather peak flow rates to within the capacity of the sewer system and the treatment plant. Implementing the recommendations will not be inexpensive, but phasing of the work in accordance with the priorities established will address the most serious concerns first and provide the most cost effective approach to correcting the overall problem.

COMBINED VERSUS SEPARATE SEWERS FOR FUTURE DEVELOPMENTS : A CASE STUDY IN MONTREAL

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ABSTRACT

Under provincial regulation, the City of Montreal is required to separate wastewater and stormwater for all new developments. This even applies to small areas enclosed into an existing urban watershed drained by a combined sewer network. In some cases, this situation can generate significant costs because of the need to prolong the stormwater pipe to an appropriate outfall.

Based on environmental analysis and on investment comparison, we demonstrated for one watershed situated in the City of Montreal, that pursuing the development of the combined sewer network for new urbanized areas, associated with in-line retention and real-time control, is cheaper and it reduces the impact to the environment. The demonstration was obtained through the development of a sewer model, calibrated on rainfall and overflow recordings.

KEYWORDS : combined sewer overflow, urban wet weather pollution, global planning, selection of sewer type, real time control modeling.

INTRODUCTION

New developments in the City of Montreal are restricted to a few urban watersheds, and about 90% of the existing sewer networks are combined. For more than twenty years, provincial regulations demand the implementation of separate sewer systems for all new urban development and give priority to the separation of the tributary collection system. Until recently, special authorization could be obtained to continue combined sewer construction in predominantly urbanized watershed already served by a combined sewer network. For the last two years, the authorities are uncompromising in their regulation's application. Their recent acknowledgement of the impacts of combined sewer overflow (CSO) seems to be the main cause.

In view of this, the City of Montreal has chosen to perform a detailed analysis on one case study in order to compare the benefits of combined versus separate sewers for new small development areas enclosed in a combined sewershed. The case study concerns ZONE 01, a residential development project, which forms part of the Marc-Aurèle Fortin watershed. This watershed is already more than 82% urbanized and ZONE 01 only represents 11% of the total area. Table 1 shows the zoning and the corresponding surface area, and figure 1 presents a simplified map of the watershed.

The main collector of the Marc-Aurèle Fortin (MAF) watershed is linked to the North Interceptor of the Montreal Urban Community (MUC). It is a combined sewer and has the capacity to accept flows from ZONE 01. ZONE 01 is located 1480 meters away from the downstream regulation and interception chambers. The interception system consists of a 30 kilometer long tunnel ranging in size from 3.35 to 4.88 meters in diameter. Its capacity is 45 m^3/s and it runs along the North border of the Island of Montreal. Twenty (20) derivation/regulation chambers control the flows from the combined collectors to the interceptor. The interceptor drains a total of 12 000 ha of urbanized area. Automated gates regulate the inflows to the North Interceptor, and local dynamic control is applied at each regulation chamber. The system is designed to maximize inflow from each site. The MAF watershed is located 9 km upstream from the end of the North Interceptor that is, at the wastewater treatment plant. Figure 2 shows a diagram of the MUC interceptor system.

Table 1 : Zoning and corresponding surface areas of the Marc-Aurèle Fortin watershed

Zoning	Surface area (ha)	Surface area (%)	Impermeability effective (%)
Residential	63.6	36	43.3
Commercial, institutional and industrial	68.1	38	74.8
Green spaces	7.4	4	1.7
Undeveloped land			
Zone 01	20.4	11	31.0
Others	11.6	7	0.0
Highways	7.8	4	43.0
Actual Total	178.8	100	45.8
Total after Zone 01's development	178.8	100	49.6

METHODOLOGY

The methodology to compare options to either develop ZONE 01 in combined or separate sewer network focused mainly on environmental assessment and cost analysis.

Stormwater runoff transports a significant pollutant load leaching from urban areas. It represents a high proportion of pollutants present in combined sewer overflows. The same pollutants are present in stormwater pipe discharge, albeit with different concentrations (Chocat, 1994; OTV, 1994). Hence, in both cases, the environmental analysis has to consider the impact of either stormwater or combined sewer overflow, although usually impact analysis are only prescribed for CSOs.

The analysis used the following tools:

- A detailed representation of the hydrology and hydraulics of the MAF watershed with the RUNOFF and EXTRAN blocks of XP-SWMM. The model was calibrated against data obtained from an extensive monitoring campaign;

- A modeled representation of the real time control (RTC) system of the MUC interceptor. This was needed because some events and configurations on ZONE 01 affected CSOs not only on the MAF watershed, but also downstream along the interceptor, because of the presence of the RTC system. The MUC model was custom designed twenty years ago. It includes runoff representation of tributary sewershed and collectors, a time-lag routing method for the interceptor hydraulics, and local dynamic control at each regulation site;

- All simulations for rainfall events from an average year (May 1st to October 31st) to evaluate impacts generated by common and frequent events.

- An evaluation of CSO discharge to the Des Prairies River (the receiving water body), in terms of flow and suspended solids, BOD, and COD loading;

- Cost estimation for each alternative.

SEWER DEVELOPMENT ALTERNATIVES

Three distinct options have been retained for the Zone 01's development:

1. Combined sewer, option A : Implementation of local combined sewer linked to the existing main collector;

2. Combined sewer, option B : Implementation of local combined sewer linked to the existing main collector. Use of the in-line capacity of an existing 2400 mm Ø main sewer, by adding a control gate, instrumentation and control. The retention capacity is designed to create no more overflows than at present;

3. Separate sewer option : Implementation of local separate sewers. Installation of a new storm sewer and a new sanitary sewer from ZONE 01 to the derivation/regulation chamber of the existing combined collector. The sanitary sewer would be directly linked to the interceptor, without regulation, while the storm collector would be connected to the CSO outfall pipe.

RESULTS

Calibration of the model was performed against 1995 data. Five rainfall stations were used for the entire MUC territory, and flow data and RTC data were available for all 6 CSO events recorded at the MAF watershed. Table 2 shows the comparison between measured and simulated overflows. The MUC model provides a good estimate of the CSO volume and duration, despite the scale of the territory versus the number of rainfall stations, the number of inflows to the interceptor, and the operating conditions.

Table 2 : Measured and simulated overflow comparison for real development

Rainfall			Measured	Simulated	
No	Depth (mm)	Duration (h)	Duration (min)	Volume (m^3)	Duration (min)
5	22.1	7.25	140	11 250	155
9-10	25.7	10.42	555	15 525	300
22	35.3	9.92	275	21 150	240
23	19.6	2.92	100	2 775	80
27	11.9	3.25	95	4 050	120
39	17.8	7.08	140	10 050	155
Total			1 305	64 800	1 050
Average			218	10 800	175

Charts 3 and 4 present CSO volumes at the Marc-Aurèle Fortin site, and at 5 other sites downstream in the interceptor. These evaluations were made under existing conditions but including the development of ZONE 01. First, we notice that Zone 01's development generates no new CSO events. Second, results show a total overflow increase of 613 m^3/s due to Zone 01's development, of which most of it, 575 m^3/s, is generated at the MAF site.

Table 3 : Annual CSO at the MAF overflow site

	Real development	Zone 01 with overflow	Increase	
	Volume (m^3)	Volume (m^3)	Volume (m^3)	Volume (%)
Total	64 800	68 250	3 450	5%
Average	10 800	11 375	575	5%

Table 4 : Annual CSO at the MAF overflow site and at 5 other downstream overflow sites

	Real development	Zone 01 with overflow	Increase	
	Volume (m^3)	Volume (m^3)	Volume (m^3)	Volume (%)
Total	385 725	389 400	3 675	1%
Average	64 287	64 900	613	1%

From these results, we can proceed to compare CSO according to the different development options.

The pollutant loadings are evaluated with the use of average concentrations during wet weather. We estimated there was no need to use a model to represent the variability of pollutant concentrations, since the purpose of this exercise is to compare options. The average concentrations are based on results from past studies and our monitoring experience in numerous cities. Their range in value also correspond to those presented in different publications.

Table 5 : Average concentrations during wet weather according to network types

Parameters	CSO	Stormwater
Suspended Solids (mg/l)	175	85
BOD5 (mg/l)	100	15
COD (mg/l)	270	85

Table 6 shows the resulting flow and pollution loads of the different development options.

Table 6 : Wet weather discharge and costs estimates for each development option

	Current	Combined option A	Combined option B	Separate option
Number of discharge events	6	6	6	32
Volume (m^3)	64 800	68 475	64 350	79 450
Suspended solids (t.m.)	11.3	12.0	11.3	12.6
BOD5 (t.m.)	6.5	6.8	6.4	6.7
COD (t.m.)	17.5	18.5	17.4	18.7
Costs estimate (US $)		$2 800 000	$3 200 000	$6 200 000

DISCUSSION

Table 6 results clearly show that developing a combined sewer network under option A on Zone 01 is the most economical option. Option B, that is option A with added in-line retention, is slightly more costly, although it does not include management, operation and maintenance annual costs. Building a separate sewer system is much more costly than the two combined sewer options.

From a technical point of view, developing a separate sewer system demands the implementation of two parallel sewer networks connected to the interceptor chamber and the overflows interceptor on 1480 m of land and roads already cluttered with underground infrastructures. The costs are important and it is commonly believed to be justified because of the benefits to the environment. The present case demonstrates the opposite. This is due to two principal factors: the discharge evaluation includes both CSO and stormwater discharge into the Des Prairies River; the interceptor system with RTC has a significant residual capacity to intercept most wet weather flows.

The combined sewer, option B with in-line retention, presents comparable discharge to current conditions, while the combined sewer, option A, presents higher pollutant discharge. Option B represents the context where combined sewer system extensions would be allowed if CSO would not increase. Results show the retention need would equal 613 m^3 to ensure an annual CSO equal to present conditions. The added benefit of adding flow regulation to profit from in-line retention seems marginal: there are no changes in the annual number of CSO events, and CSO volumes and loading are reduced by 6%.

The MUC interception system has significant residual capacity for wet weather flow control thus allowing a limited overflow frequency. This is particularly true for the downstream CSO sites along the North Interceptor. Our evaluation shows that an important proportion of flows generated by the ZONE 01 development can be intercepted. As a result, there is little increase in CSO volume and it is limited to only a few events each year.

The interdependence between upstream and downstream sections of a network leads to evaluate the effects of new developments not only individually, but globally (Valiron and Tabuchi, 1992). Taking such a global perspective could lead to more pertinent solutions to improve the quality of the environment, such as for example seeking lower CSO frequency from the North Interceptor. The average number of CSOs from 1994 to 1996 varies from 1.3 to 12.3 annually and from site to site. A study performed by the MUC in 1995 indicates that investments in the order of 55 M$ US would be needed to significantly reduce the number of CSO events to 4 times per year. To attain this goal, an additional 87 000 m^3 retention capacity would be required. This represents a concrete objective showing the intervention level needed to adequately protect the environment.

CONCLUSION

An environmental and cost analysis was performed to compare how a new development project included in a combined sewershed should be better sewered: with separate or combined sewers. The case study is taken from the Marc-Aurèle Fortin watershed in the City of Montreal.

It is demonstrated through an extensive analysis that for this case study, building a separate sewer system on the new development project, ZONE 01, enclosed in a combined sewershed, would be much more costly and discharge more pollution to the Des Prairies River than if developed as a combined sewer network, including equipment to benefit from in-line retention capacity in an existing collector. As a result, we find that applying generic regulations may be detrimental when arbitrarily applied. In many cases, this is particularly true when assessing whether to develop a separate or combined sewer for new urbanized areas and overlooking the effect on the receiving water body.

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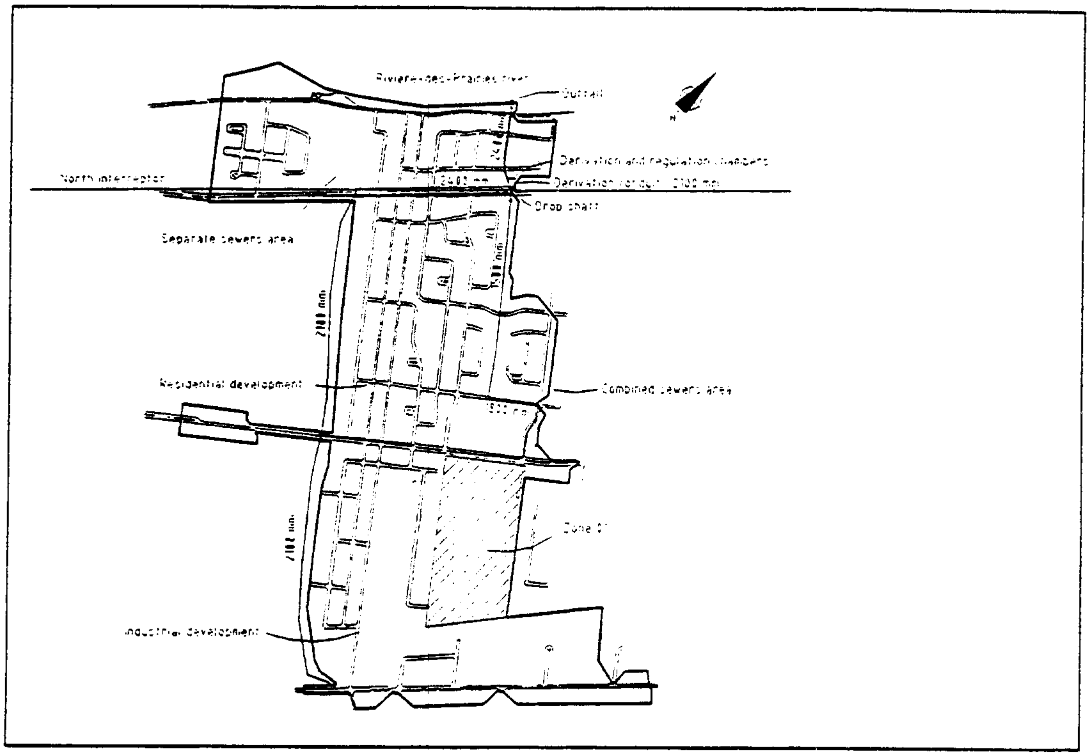

Figure 1 : Marc-Aurèle Fortin watershed

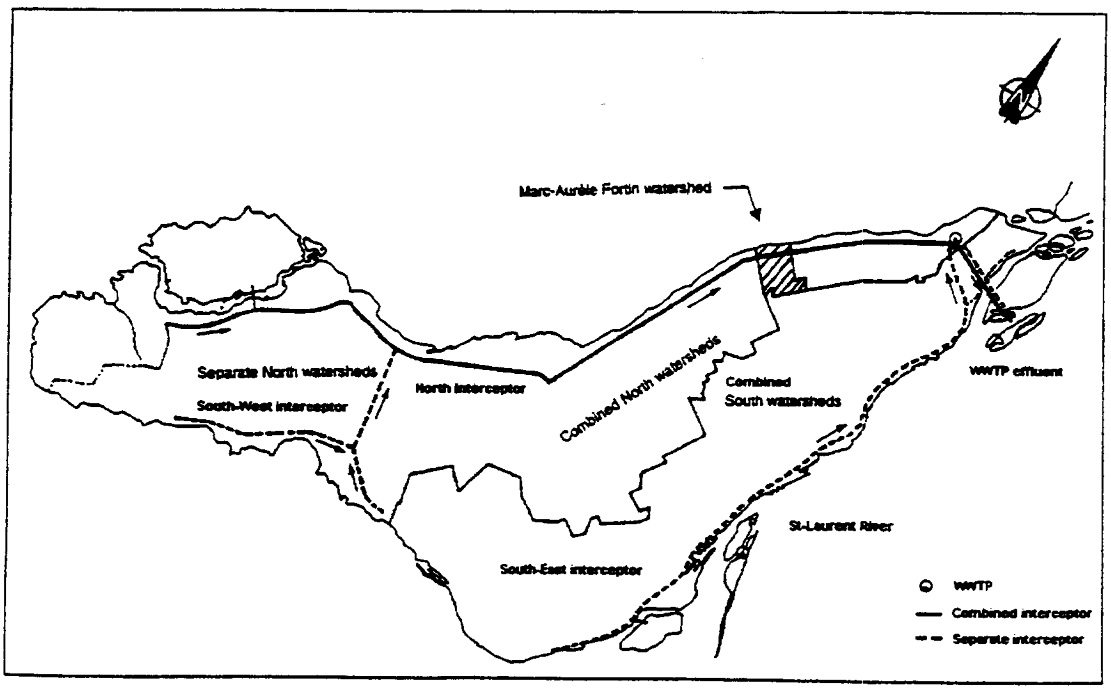

Figure 2 : MUC interceptors network

R0025201

Simulating Water Quality in the Duwamish Estuary and Elliott Bay: Comparing Effects of CSOs and "Other Sources"

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ABSTRACT

King County (Washington) Department of Natural Resources is completing a water quality assessment that compares the Human Health and Aquatic risks from existing combined sewer overflow (CSO) discharges with the risks from other contributing sources (e.g., stormwater, surface run-off, groundwater, etc.).

King County selected the 3-dimensional Environmental Fluid Dynamics Computer Code (EFDC) model to simulate density flow and toxicant transport and fate of the contaminants within the Duwamish Estuary and Elliott Bay. The Duwamish Estuary is located in the heart of Seattle's industrial area. It is a heavily used shipping channel and is a significant habitat area for salmon. The estuary is well stratified (salt-wedge type) and the position of the wedge toe is very dynamic, being controlled by tides and fresh-water flow.

An intensive 26 week field sampling program was performed to collect water and sediment chemical data for the toxicant transport and fate module. Physical data was collected over a ten month period for the hydrodynamic module. Results from the modeling effort are being used in a Human Health and Aquatic Risk Assessment (RA) to compare potential exposure to humans, plants and animals from CSOs and other sources.

This paper focuses on the modeling techniques used and the assumptions and results from the modeling effort. It also presents an overview of the Water Quality Assessment, including the monitoring and sampling program.

KEYWORDS

Water quality modeling, CSO impacts, water quality assessment, toxicant transport

INTRODUCTION

King County owns and maintains the wastewater treatment plants and large conveyance pipes, collecting wastewater from Seattle and most of the smaller cities within the county boundaries. In parts of the conveyance system, the system is connected to both sewage and stormwater lines in what is termed a combined system. During periods of dry weather the conveyance system transports mainly sewage to the treatment plants. When the county experiences a significant rainfall event, the capacity of the conveyance system is exceeded thus forcing combined sewage and stormwater to overflow into the local water bodies surrounding Seattle. These sites are termed combined sewer overflows (CSO). CSOs only discharge when the ability of the conveyance system to transport sewage is exceeded due to the rainfall event. Currently the largest number of CSOs are in the Duwamish Estuary; hence the focus of this study is in the estuary. (See Figure 1)

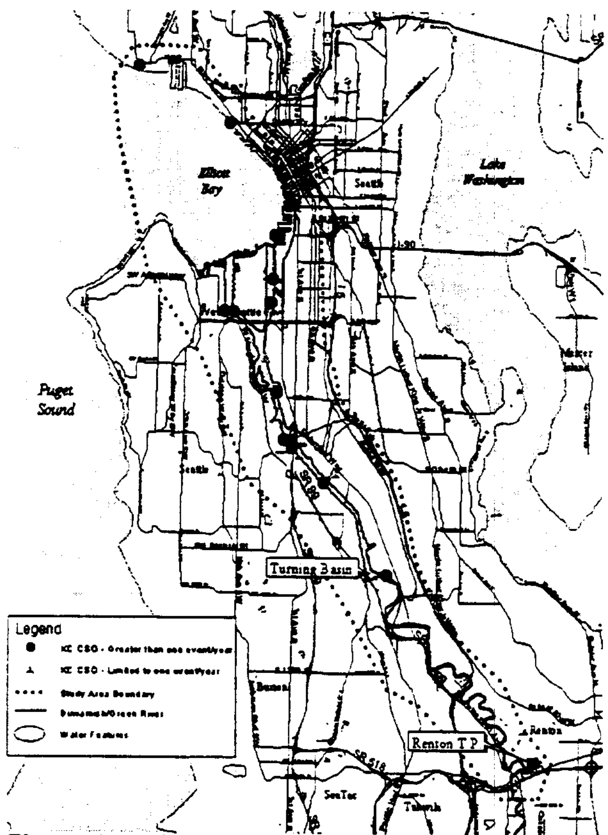

Figure 1. WQA study area

The Department of Ecology (DOE) requires the county to keep records on the number of discharges, volume of overflow, and chemical content of CSOs as part of the National Pollution Discharge Elimination System (NPDES). King County made agreements with DOE to reduce the number of CSO discharges from all sources to one untreated event per year, without a specific deadline for achievement of this standard. Federal standards allow four to six untreated discharges per year.

As part of the county's commitment to maintain or improve water quality, it embarked on the task to determine how significant CSO discharges into the Duwamish Estuary are compared to other contaminant sources that discharge into the estuary as well. The project, called the Water Quality Assessment (WQA), looks at the risk to human health and aquatic life as it exists today and what it would be without CSOs discharging into the estuary. To assess risk, the county is using chemical concentrations in the water, sediments, and aquatic life (primarily fish). Values for the water and sediment chemical concentrations will be obtained from a computer model that has been calibrated against observed field data.

Chemicals of Potential Concern

Eutrophication is not a problem in the Duwamish Estuary and Elliott Bay. Sampling of dissolved oxygen revealed that DO concentrations were always above 7 mg/l, even during CSO events. Flow through the estuary is rapid enough such that no other eutrophication processes pose significant risk to aquatic life. The chemicals that are of potential concern (COPC) in the estuary and bay were selected based on availability of data, water and sediment standards, and those known to impact the health of humans or aquatic life. The COPCs modeled in this risk assessment are,

- Metals
  - Arsenic, Cadmium, Copper, Lead, Nickel, Zinc, Mercury, Tributyltin
- Organic Compounds
  - 1,4 Dichlorobenzene, 4 Methylphenol, Bis(2 ethylhexyl)Phthalate, Fluoranthene, Phenanthrene, Total PCB, Pyrene, Benzo(k)Fluoranthene, Chrysene, Benzo(b)Fluoranthene
- and Fecal Coliforms.

Use of a computer model for the WQA study is twofold: 1) it will be used as a mass balancing tool to estimate chemical contributions from other sources given CSO, ambient, and boundary chemical loads, and 2) it will be used as a surrogate field sampling program. This paper discusses how the model was prepared and applied for the WQA risk assessment.

The Duwamish Estuary

The Duwamish Estuary is located in the heart of Seattle's industrial area southwest of downtown, and flows north into the southern tip of Elliott Bay. It is a heavily used shipping port and is a significant habitat area for salmon and other wildlife. The estuary is defined as the body of water starting from the mouth at Elliott Bay to 18.5 kilometers upstream. Most of the estuary is dredged for shipping with dredging extending approximately 12.5 kilometers upstream from the mouth. The mean river flow is about 42.5 cms (1500 cfs). The estuary is well stratified (salt-wedge type) when fresh-water inflow rates are greater than 28 cms (1,000 cfs); but when flows are less than 28 cms, the lower 5.5 kilometers of the estuary grades into the partly mixed type. Cross-channel distribution is generally uniform for a given location and depth. Salinity migration is controlled by tides and fresh-water flow. The upstream extent of the wedge is dependent upon fresh-water inflow and tide height and can range from 2 to 16 km upstream from the mouth. Dye studies indicate that downward vertical mixing over the length of the salt-wedge is almost non-existent.

Freshwater flow into the estuary comes from the Green River. The river is regulated at the Howard Hanson dam for flood control. However, flow rates do vary considerably day to day because of storm runoff and snow melt. Upstream tidal flow reversal has been observed in the Green River 21 km upstream of the mouth.

Water depth in the dredged sections of the estuary vary from 15 meters at mean lower low water (MLLW) at the mouth to 3.6 meters at 14th Ave bridge (9.5 km). The channel above the turning basin is not dredged and varies in depth from 1 to 2 meters (MLLW). Elliott Bay, at its deepest location, is about 150 meters (MLLW). Tides in the Duwamish have ranged from minus 1.4 to plus 4.5 meters from mean lower low water. Freshwater flow from the Duwamish discharges into Elliott Bay causing a freshwater lens atop the saline waters in the bay.

MODELING OBJECTIVE

The objective of the modeling program was to use the computer model as a mass balancing tool to determine mass loading contributions from sources other than CSOs. The model was then used to assess the differences in resulting water and sediment concentrations due to CSOs and "other sources". These differences could then be used in a Risk Assessment to quantify the risk to humans and aquatic life from CSOs relative to "other sources". Therefore, it was assumed that there are three basic chemical sources in the estuary: boundaries, CSOs, and "other sources". King County had limited financial resources and limited it's scope of work to collecting information on CSO chemical compounds and ambient chemical concentrations. Knowing two of the three sources, the computer model was employed as the third equation to estimate inputs from the other chemical sources.

COMPUTER MODEL DESCRIPTION

King County selected the Environmental Fluids Dynamic Computer Code (EFDC) developed by Dr. John Hamrick for application to the WQA modeling. It was selected over other models because it can simulate highly stratified flows and both nutrients and toxic compounds. It has been applied to many estuarine studies, and it is non-proprietary. The county reviewed 13 different models for application to the Duwamish. They were rated against a set of requirements defined by the county which were based on the needs of the WQA and observed conditions within the estuary. (See Walton, 1998)

EFDC is a curvilinear-orthogonal, three dimensional hydrodynamic-chemical transport and fate model. The hydrodynamic and transport modules are coupled. The vertical dimension is transposed into a stretching coordinate system where cell layers move with the free surface. Hydrodynamics are solved using the depth integrated momentum equation and employs a turbulent intensity and length scale transport equation to solve for turbulent viscosity and diffusion. Transport and fate is solved using the mass transport equation and incorporates a near field model which can be coupled to the mass transport model. For a detailed explanation of the model derivation see Hamrick (1992).

The study area was segmented into 500 cells in the horizontal plane, and ten layers in the vertical for 5,000 cells in total. The EFCD model was modified to simulate near-field CSO effects within the larger model cells, and to simulate chemical fate equations as a function of the physical and chemical state of the estuary and bay.

FIELD MONITORING PROGRAM

Water velocity, elevation, temperature, and salinity were collected during the field monitoring program. Acoustic doppler current meters were used to measure water velocity. Three meters were deployed in the estuary and two in Elliott Bay. The meters measured the horizontal and vertical components of the water velocity. Velocities were measured at half-meter intervals in the estuary and at 4-meter intervals in Elliott Bay. Salinity, temperature, and water elevations were measured at three field stations in the estuary. Two stations had two instruments placed one meter below the surface and one meter above the bottom. The third station had a single instrument placed one meter below the surface.

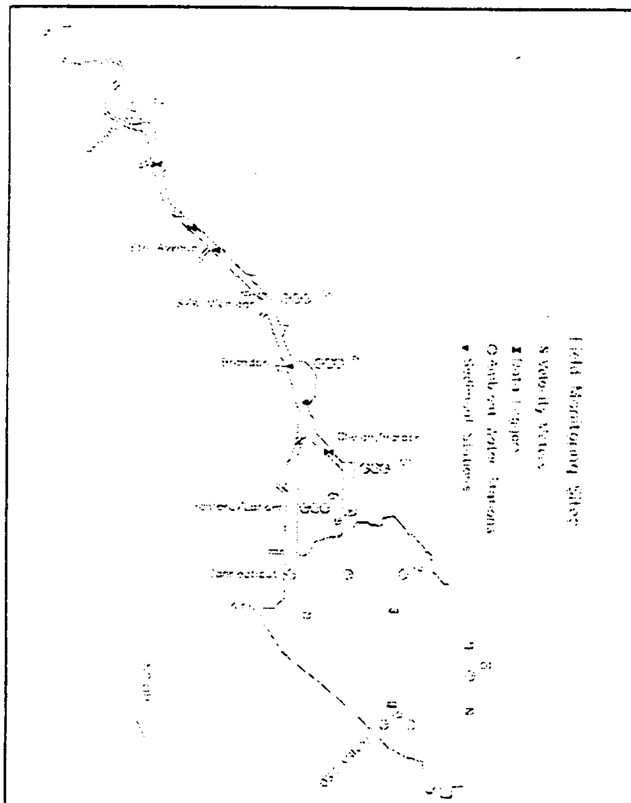

Figure 2. Locations of sampling and field instrument sites.

To determine the feasibility of an intense field sampling program, King County did a pilot study to see if it was possible to collect the number of samples required and if current laboratory analytical techniques were appropriate. The pilot study revealed that most of the organic compounds were non-detects and the saline water of the estuary significantly interfered with measuring metals. The County instigated new laboratory procedures to remove the saline matrix from the water samples, also lowering the detection limit by an order of magnitude. To overcome the inability to measure organic compounds using conventional laboratory procedures, Semi-Permeable Membrane Devices (SPMD) were used. The SPMDs were deployed for two weeks and provide a time averaged estimate of water concentrations over the deployment period. Organics were still sampled using conventional methods approximately once per month and except for Bis(2-ethylhexyl)Phthalate, all other organic COPCs were non-detects.

The field monitoring program was started October 31, 1996 and ended June 4, 1997. Approximately 26 sampling trips where performed during this time period.

Samples were taken either once or three times per week. If the three largest CSOs were not discharging (non-storm event), one sample was collected for that week. If the three CSOs were discharging (storm event), then sampling occurred over three consecutive days. Personnel were put on 24 hr alert, 7 days a week to mobilize for storm sampling. For safety reasons, it was decided that sampling would only occur during daylight hours. Because of this, some storm sampling trips did not commence until the tail end of the storm period when CSOs had slowed considerably.

Sampling locations were selected along the length and width of the estuary, see Figure 2. Samples were taken 1 meter below the surface and one meter above the bottom at most river sites. Samples were

Table 1. Quantities Measured for COPCs

Chemical Of Concern	Measuring Technique	Measured Quantity	
		Water	Sediments
Metals: As, Cd, Cu, Pb, Ni, Zn	Standard Analytical Methods (SAM)	T,D	T,TOC,TS
Organic:			
1,4-Dichlorobenzene,	SAM	T,D,TVS	T, TOC,TS
4- Methylphenol,	SAM	T,D,TVS	T, TOC,TS
Bis(2-ethylhexyl)Phthalate,	SAM	T,D,TVS	T, TOC,TS
Total PCBs,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Pyrene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Benzo(k)Fluoranthene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Fluoranthene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Phenanthene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Chrysene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Benzo(b)Fluoranthene,	SPMD,Mussels	TAT,TVS	T, TOC,TS
Others:			
Mercury	Ultra-Clean Methods	T,D	T,TVS
Fecals	SAM	T	
Tributyltin	Mussels	TAT	
Total Suspended Solids	SAM	0.45	PD

T Total Concentration
D Dissolved Concentration
TOC Total Organic Carbon
TS Total Sulfides
TVS Total Volatile Solids
TAT Total Time Averaged Concentration
PD Phi Size Distribution
0.45 0.45µ Filter

taken 15 to 20 meters below the surface in Elliott Bay. Samples were taken at 3 locations across the river at most of the river sites. The parameters measured are listed in Table 1.

CSO contaminant concentrations were obtained by sampling five of the largest CSOs that discharge along the Duwamish. They were Brandon, Connecticut, King, Hanford, and Chelan Regulators. The sampling program was designed to test whether chemical concentrations changed over the duration of the discharge event (first flush effects), whether they varied between CSO outfalls, or whether they varied across the depth of the CSO pipe. Additionally, previous testing results were available for the Denny Way CSO site regarding chemical analysis, and solids settling, and how metals partition to suspended solids.

Sampling QA/QC

Collection of water samples was started before the County had developed the analytical techniques to remove the saline matrix from the samples. The new technique lowered detection levels an order of magnitude below what was previously achievable. While this was good, it also proved to be a problem. The lower detection limit increased the degree to which sample contamination could be observed. Standard QA/QC revealed significant field blank contamination had occurred in most samples for lead, copper, and zinc. The sample values were subsequently blank corrected using the limited information that was available.

MODEL CONFIGURATION

John Hamrick from TetraTech Inc. configured the model with assistance from King County staff.

Elliott and Duwamish Boundary Conditions

At the model boundaries, Elliott Bay is forced by a phased harmonic tidal series. The Harmonics and phasing where determined from water level time series data taken near Fourmile Rock and Alki Point. The phasing accounts for the time it takes the tidal wave to travel across the boundary length. At the upstream I-405 Green River boundary tidal effects are minor. Conditions at the Green River boundary were driven by fresh water flows obtained from the USGS flow station at Auburn. Daily average flows were used.

Chemical data gathered from the field monitoring program at the Tukwila and Duwamish Head field stations were used at the Green River and Elliott Bay boundaries respectively for model calibration. Boundary conditions for the one-year and ten-year simulations were generated from a simple stochastic model developed from observed data. Correlation analysis of the Tukwila data indicated a significant relation between zinc, lead, and copper, but less so with nickel. No significant correlation existed for arsenic and cadmium. Analysis of the Duwamish Head data at the 20 meter depth indicated a correlation between cadmium, copper, and arsenic. Analysis of all data indicated no significant correlation between river flow, rainfall, or CSOs. Data generation for both boundaries entailed generating a primary constituent with the same statistical properties as the observed field data, and then generating the other constituents from the primary, maintaining the observed correlation.

CSOs

Currently 13 King County CSOs discharge into Elliott Bay and the Duwamish Estuary. Hydrographs used for the calibration are from flow data recorded over the 96-97 year. Hydrographs for the ten-year runs were generated from the county's basin run-off and hydraulic routing models and historical rainfall data from a recent ten year period. The rainfall periods were matched to the historical Green River flow data at the Auburn station.

Analysis of the chemical data from the CSO monitoring program indicated that there were was no significant change in concentrations over the duration of the discharge. Concentrations appeared to vary over the depth of the pipe, and that there were subtle differences in concentrations between a few of the CSOs and a few of the metals of concern. As a result, average concentrations for each of the five CSOs for each of the COPCs were used in the model. For the remaining seven CSOs that were not monitored, concentrations were estimated from one of the five CSOs based on similar basin characteristics, see Appendix A for grouping and concentrations.

Other Sources

The actual number of other sources that discharge into the Duwamish Estuary and Elliott Bay are unknown. However, an estimate of total run-off into the estuary was modeled using the County's basin run-off model. The county currently maintains a basin run-off and conveyance model for the Westpoint and Renton treatment plants to estimate sewer flow through the pipe network. The model is calibrated to observed flows in the sewer conveyance system and includes effects from stormwater inflows generated by rainfall. The portion of the stormwater from impervious areas flow that does not enter the sewer system was considered to drain into the storm system. Run-off flow was routed along basin drainage lines and discharged into the Duwamish and Elliott Bay as an other source. Forty-one discharge hydrographs of stormwater were generated from the run-off model.

Chemical input for the other source loads was obtained from historical stormwater data. Since the intent of the modeling was to estimate chemical loads from other sources, stormwater chemical concentrations were adjusted until model predictions were comparable to observed data. Exact concentrations were not required, only reasonable estimates were needed. Use of the stormwater data does not imply all loads from "other sources" are solely from stormwater drains. The review did not provide stormwater chemical data for some of the COPCs. In these instances, non-sewage-related CSO data was used. Appendix A summarizes initial chemical conditions for other sources.

Sediments and Suspended Solids

Sediment concentrations from Elliott Bay and the Duwamish were obtained from the DOE SedQual database. This data set was supplemented with data collected from the WQA. Sediment particle size for the bay and estuary was obtained from GeoSea Consulting which gathered the data for the Elliott Bay/Duwamish Restoration Program. This data was also supplemented with particle information collected by Science Applications International Corp 1991 for ACOE dredging at the turning basin. Very little sediment chemistry and particle data information is available for the Green River section of the model. A small amount of particle size information was obtained from an in field assessment of percent fines, at four locations, by county technicians. Anecdotal evidence from the USGS was also used. The data was collated to initialize sediment concentrations and particle distribution within all model cells. Multiple points within a single cell were averaged into a single value. Cells with no data points were interpolated from neighboring cells.

Review of all the sediment and CSO sampling data indicated that the sediments could be divided into three general classes, fine sand to course silt, silts, and fine silt to clay. Solids concentrations at the Green River boundary for fine sand/course silt class were generated using the Corps of Engineers Suspended Solids Loading Equation (ACOE 1981). Concentrations for the finer solids were generated from a similar regression equation using TSS field data collected for the WQA and USGS Auburn flow data. The field monitoring program provided suspended solids concentrations for CSOs. Solids concentrations for other sources were obtained from existing stormwater studies.

Chemical Properties

Chemical partition values for the metals As, Cu, Cd, Pb, Ni, and Zn were estimated from field data using the following equation (Thomann 1987),

Equation 1

$$P = \frac{c_T - c_d}{c_d m}$$

Where:
P is the partition coefficient
c_T is total chemical concentration
c_d is dissolved chemical concentration
m is total suspended solids concentration

An average partition coefficient was computed for each sample site and the sample averages were combined to compute a single partition coefficient. A constant partition coefficient was used for all chemicals. However, sample averages indicated that partitioning varied along the length of the estuary. An attempt was made to develop a regression equation to explain the observed relation between salinity and the partition coefficient, but none of the equations proved to be statistically significant. Chemical partitioning for the organic compounds, Tributyltin, and Mercury were obtained from literature references (Hamrick 1998).

Table 2. COPC Chemical Properties

Chemical of Concern	Decay (1/sec)	Partition Coefficient (l/mg)	
		Water	Sediments
Arsenic	None	0.02	0.005
Cadmium	None	0.018	0.004
Copper	None	0.11	0.025
Lead	None	4.4	0.4
Nickel	None	0.042	0.01
Zinc	None	0.082	0.02
Tributyltin	None	1.0e-3	Same
1,4-Dichlorobenzene	None	8.1e-5	Same
4- Methylphenol,	None	2.4e-6	Same
Bis(2-ethylhexyl)Phthalate	3.5e-7	4.8e-3	Same
Fluoranthene	3.1e-6	9.8e-3	Same
Phenanthrene	7.7e-6	8.4e-4	Same
Total PCBs	None	2.2e-3	Same
Pyrene	9.4e-5	3.4e-3	Same
Benzo(k)Fluoranthene	3.9e-7	3.0e-1	Same
Chrysene	1.5e-5	2.1e-2	Same
Benzo(b)Fluoranthene	2.7e-7	1.5e-1	Same
Mercury	None	4.4e-4	Same

Chemical decay rates for the organic compounds were obtained from literature references (Howard et al 1991). Minimum rates were used for both water and sediment columns. A zero decay rate was used for unlisted chemicals. Partition and decay values are summarized in Table 2.

MODEL CALIBRATION

John Hamrick calibrated the hydrodynamic portion of the EFDC computer model and sent the calibrated model to King County staff for the mass calibration of the COPCs.

Sediments

The first constituent to calibrate was the suspended solids. The only parameter adjustment was the suspended solids settling velocity. While the model requires specifying a critical sediment stress at which resuspension occurs, no field measurements were made to estimate a critical stress value. Instead literature references were used as suggested by Hamrick (1.6e-4 $(m/s)^2$ non-cohesive and 1e-4 $(m/s)^2$ cohesive). At first, two sediment types were selected; fine sand and silt. Sediment samples from ACOE (SAIC 1991) pre-dredging studies indicated that most of the solids deposited in the turning basin are fine to medium sands. A third solids class was added with a settling velocity similar to clays and flocculated material due to the fact that too much sediment was settling out. The solids in the CSOs were also divided into silts and clays, with the same settling velocities as those used in the river.

Settling velocities and solids loadings at the Green River boundary were adjusted for all three classes until an optimum fit between observed and predicted solids concentrations was reached. The best fit occurred with a suspended solids distribution at the Green River boundary of 78% fine sands, 15% silts, and 7% clays, and 100% clay at the Elliott Bay boundary. Suspended solids from CSOs and other sources were negligible compared to that from Green River. Final settling velocities for each class was 0.01 m/s for the fine sands, 0.004 m/s for silts, and $1x10^{-6}$ m/s for the clays. The final calibration graph for total suspended solids at the Brandon site are shown in Figures 3 and 4, for the surface and bottom levels.

Metals

Metals were calibrated after the sediment calibration was completed. Calibration entailed adjusting load inputs from "other sources" until simulated metals concentrations were comparable to observed data. Metals loading from CSOs were not adjusted, since it was assumed that inputs from CSOs had been adequately defined in the sampling program.

The model simulated the transport of metals in two phases, dissolved and particulate. Division between the two phases was defined by the partition coefficients given in Table 2 and the suspended solids as given by equation 1. It was assumed that the partition coefficients remained constant in both space and time. Given that the partition coefficient does not vary, and that the suspended solids field has been defined; differences in simulated and observed metals concentrations were ascribed to other source loads. The model simulates chemical loads using a hydrograph and chemical concentration time series. It multiplies the flow rate by the chemical concentration to give a chemical flux into the cell. To adjust the load that discharges into the cell, either the flow rate or the chemical concentrations can be manipulated. For the EFDC model it is easier to manipulate the chemical concentration time series rather than the hydrograph.

Calibration was carried out in a series of steps, each step refined the previous steps. The first steps were to match the general fit of model predictions to field observations. After the general fit was completed the next steps refined model predictions at specific points in the observed time series. This entailed adjusting either the existing hydrographs, chemical time series, or adding a separate hydrograph and chemical time series as needed to match observed field data. Final calibration graphs for zinc at the Brandon site, 1 meter below the surface and 1 M above the bottom, are shown in Figures 5 and 6.

Organic Compounds

The organic compounds were calibrated using sample data from mussels and SPMDs. The concentrations in the mussel tissue were converted to average concentrations in the water column which would approximately result in the sampled tissue concentration. Concentrations in the SPMDs were placed in the water for two weeks. The concentration of contaminants in the SPMDs were converted to average water column concentrations that would result the SPMD values. Data from the model was saved and averaged over the time periods that the mussels and the SPMDs were in the water.

Calibration Results

Final chemical concentrations for other source inputs are listed in Table 3. Final CSO concentrations are shown in Table 4.

Table 3. Final Chemical Concentrations for Other Sources

Metals							Organics	
Other Sources	Eastside Inputs							
Source (mg/l)	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	TBT	Phenanthrene
Pre-Julian day 400	4.64	0.95	22	22.8	0.0	134	0.0	1.44
Post-Julian day 400	3.9	0.95	22	10.8	0.0	70.8	0.0	1.44
	Westside Inputs							
Pre-Julian day 400	4.64	0.9	22	26.2	7.1	156.8	0.0	1.44
Post-Julian day 400	3.9	0.9	22	20.9	7.1	114	0.0	1.44

Organics								
Source (ug/l)	Chrysene	Fluoranthene	Pyrene	1,4-Dichloro benzene	4-Methyl phenol	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Total PCB
Eastside Inputs	0.06	0.43	3.59	0.15	2.32	0.015	0.0005	0.0
Westside Inputs	0.06	0.43	3.59	0.15	2.32	0.015	0.0005	0.0

RESULTS OF MODELING

The calibrated model was run for one-year and ten-year periods. The one-year period simulation looked at differences between CSOs and other sources in the water column and estimated differences in the sediment column. Chemical concentrations were saved every hour for every model cell. The ten-year period was run to verify or correct the one-year sediment estimates. The ten-year run was necessary because of the generally slow response of sediments to loading changes, and it was not known if current sediment concentrations were in equilibrium with the existing environment.

Table 4. Arithmetic Mean Chemical Concentrations for CSO

Metals (ug/l)								
Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	Mercury (ng/l)		TBT (ug/l)
2.87	0.51	32.78	30.68	8.24	130.17	26.95		0.0
Organic (ug/l)								
Total PCB	Chrysene	luoranthene	henanthrene	Pyrene	,4-Dichloro benzene	-Methyl phenol	Benzo(b) luoranthene	Benzo(k) fluoranthene
0.0	0.242	0.43	0.439	0.363	0.382	5.62	0.239	0.208

Model results for the one-year simulations with and without CSOs have not been evaluated at the time of writing this paper. Therefore, a comparison of the impacts between CSOs and other sources has not been done at this time. However, the calibration process did reveal some information about the models ability to simulate the highly stratified conditions in the estuary, and the relative influence of boundary sources to observed metals concentrations. The model is able to give a reasonable simulation of contaminant transport through the estuary, and the results are being used to perform a Risk Assessment on the impact of CSOs relative to other sources.

SUMMARY

The Duwamish Estuary and Elliott Bay is a highly stratified flow system when CSO and other sources tend to discharge into the system. The EFDC model adequately simulated the stratified flow and transport of metals and organic compounds through the estuary and into the bay, maintaining observed chemical differences between the fresh water lens and the saline wedge. Assessment of the calibration process indicates that the most influential source of arsenic and cadimum is from Puget Sound. The Green River is the primary source for nickel.

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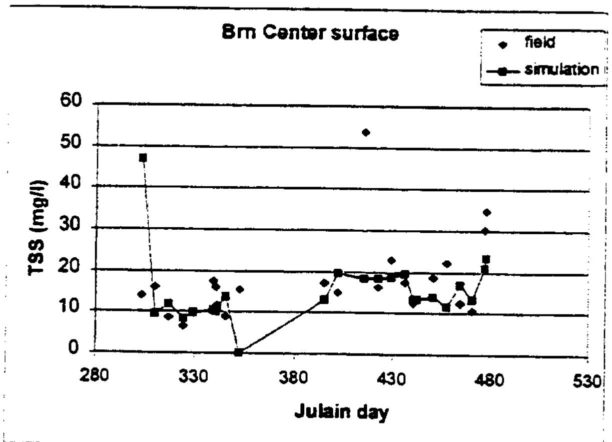

Figure 3

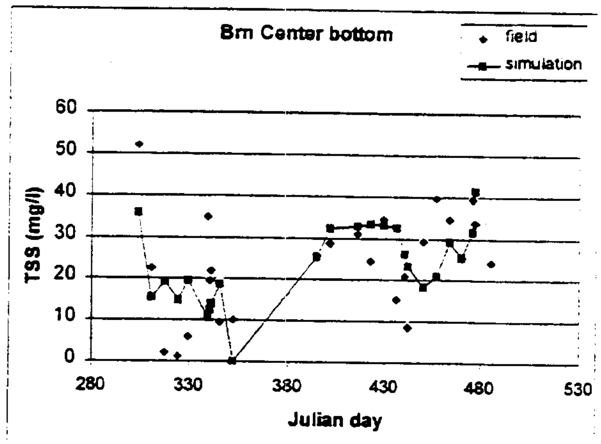

Figure 4

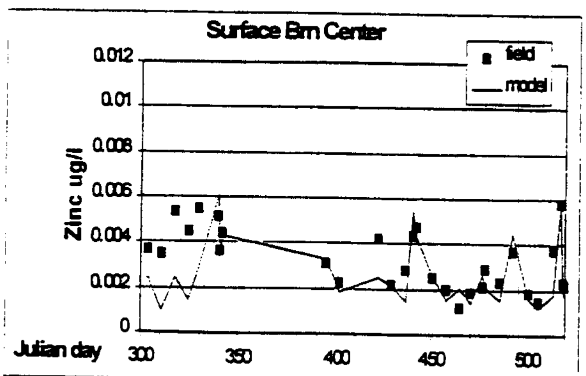

Figure 5

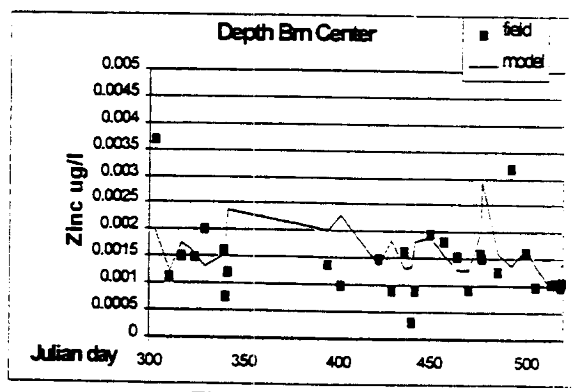

Figure 6

COORDINATION WITH STATE WATER QUALITY STANDARDS DURING DEVELOPMENT OF A LONG-TERM CSO CONTROL PLAN

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) published its final CSO Control Policy in April, 1994. In response to the new national policy, the Massachusetts Department of Environmental Protection (DEP) revised the state's water quality standards to include waterbody classifications that reflect a range of circumstances under which CSOs discharge and issued a new CSO Policy and Guidance Document, incorporating increased flexibility for permittees to demonstrate that CSO discharges are being controlled to the maximum extent feasible. The CSO control plan developed by the Massachusetts Water Resources Authority (MWRA) is the first one to be reviewed and approved under the new state policy and regulations. The planning approach used and documentation provided by the MWRA will serve as the template for other regional wastewater agencies and municipalities seeking approval of CSO control plans from Massachusetts DEP and EPA.

KEY WORDS

CSO policy, water quality standards, percent compliance, designated uses, sensitive use areas, use attainability analysis

INTRODUCTION

Recent changes in EPA and Massachusetts CSO policies now provide more options for regulating CSO discharges. Both policies require that permittees fulfill specific requirements in developing long-term control plans and that certain criteria are met to successfully demonstrate that water quality standards will be achieved and designated uses protected.

National CSO Policy

EPA's policy evolved with extensive input from numerous state, municipal, and environmental stakeholder organizations in an open participatory process. One intention of the policy was to ensure that permittees, regulators, and the public engage in a comprehensive and coordinated planning effort to achieve cost-effective CSO controls that comply with water quality standards and protect designated waterbody uses. It provides for flexibility in developing long-term CSO control plans and allows CSO controls to be tailored to address site-specific impacts of CSOs.

The policy specifically states that development of a long-term CSO control plan should be coordinated with the review and appropriate revision of state water quality standards and implementation procedures for CSO-impacted waters. Further, the policy states that this coordination process provides greater assurance that the long-term plan selected and the limits and requirements included in the NPDES permit will be sufficient to meet water quality standards and comply with the Clean Water Act.

Massachusetts CSO Policy

As a first response to EPA's 1994 national policy, DEP issued a new draft CSO strategy in August, 1995. The agency also revised its water quality standards in 1996 to provide a regulatory framework for additional waterbody classifications that would reflect the range of situations in which CSOs occur. After a dedicated public outreach process, DEP issued its final updated CSO Policy and Guidance Document in August, 1997.

The new state CSO policy and guidance reinforce DEP's original goals for CSO abatement measures:

- Eliminate receiving water impacts from CSOs.
- Where elimination of CSOs is not feasible, minimize CSO impacts to the maximum extent feasible and attain the highest water quality achievable.

In receiving waters where CSOs remain, the identification and protection of sensitive areas that support critical uses is essential. The elimination of CSO discharges through sewer separation, or relocation of CSOs to less sensitive receiving water segments, is required wherever it can be achieved based on economic and technical evaluations. To demonstrate that CSO discharges can not be eliminated, the permittee must show that the cost of sewer separation would cause "substantial and widespread economic and social impact." The DEP CSO guidance document states that the demonstration of severe economic and social impact can be made by showing that the costs of sewer separation (or CSO relocation) are excessive when compared to the benefits to be achieved. When determining the benefits to be achieved, potential interactive and overlapping pollution sources (such as discharges from storm drains after separation) can be taken into account.

The state CSO policy contains a hierarchical "menu" of surface water classifications based on the frequency and impact of overflows to regulate CSO discharges that can not be eliminated. In all cases, permittees are required to implement the nine minimum controls necessary to meet technology-based limitations specified in EPA's national CSO policy.

MWRA CSO Control Plan

The MWRA defined its long-term CSO control plan in its final CSO facilities plan, which was completed in July, 1997. In accordance with EPA's CSO policy, the recommended CSO control plan was developed over a five-year period with continual interaction and direction from DEP, the state agency responsible for enforcing water quality standards. During the MWRA CSO planning process, DEP reviewed its regulations and determined that changes in water quality standards were warranted to better reflect site-specific wet weather impacts of CSOs.

METHODOLOGY

The process leading to approval of MWRA's CSO control plan involved a concurrent, cooperative effort by DEP and MWRA. DEP established new water quality classifications and MWRA demonstrated compliance with them, using a watershed-based approach that considered each receiving water segment on a site-specific basis and that assessed control alternatives using technology-based and water quality-based evaluations.

New DEP Water Quality Classifications

DEP's CSO policy contains a hierarchical listing of surface water classifications to regulate CSO discharges based on the frequency and impact of each overflow. The classifications for CSO-impacted waterbodies are summarized in Table 1. The **Class B or SB** classifications indicate that CSO discharges have been eliminated. If CSOs are not eliminated, the regulatory options include: Class B(CSO) or SB(CSO), indicating minimal CSO impacts whereby Class B standards are met greater than 95 percent of the time; a variance, allowing a short-term modification of standards through the NPDES permitting process to provide time to gather more water quality impact information; a partial use designation, indicating intermittent impairment of water quality goals; and Class C or SC, a downgrade in classification if permanent and sustained impairment of water quality goals is documented. These classifications are discussed below.

Class B(CSO) or SB(CSO). Where elimination of CSO is not feasible and the impacts from remaining CSO discharges will be minor, the segment will be identified as B(CSO). Overflow events may be allowed without a variance or partial use designation, provided that certain conditions are met. DEP's 1996 revisions to the water quality standards regulations formally recognized the B(CSO) water quality category by establishing

TABLE 1. SUMMARY OF WATER QUALITY CLASSIFICATIONS FOR CSO-IMPACTED WATERS

Classification	Requirements
B, SB	CSOs are eliminated
B(CSO), SB(CSO)	CSOs remain but must be compatible with water quality goals
Variance	CSOs remain when allowed under a short-term modification of water quality standards through an NPDES permit
Partial Use Designation	CSOs remain with moderate impacts resulting in intermittent impairment of water quality goals
C, SC	CSOs remain, causing permanent and sustained impairment so that Class B water quality goals can not be met

Note: Class SB and SC denote coastal and marine waters

regulatory significance for the notation "CSO" shown under "Other Restrictions" in the state water quality standards for impacted receiving water segments. The following criteria must be satisfied in order to receive a B(CSO) designation:

a. An approved facilities plan provides justification for the overflows.

b. The DEP finds through a use attainability analysis, and EPA concurs, that achieving a greater level of CSO control is not feasible for one of several reasons.

c. Existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

d. Public notice is provided through procedures for permit issuance and facility planning.

A designation of B(CSO) for a particular receiving water segment will be made only if DEP's facilities planning process and watershed planning efforts show that the allowance of minor CSO discharges is the most environmentally protective and cost-effective option available. B(CSO) does not denote a downgrade of water quality, rather it indicates that Class B or Class SB water quality standards will be met most of the time and that CSO impacts were minimized to a level compatible with water quality goals.

The conditions for showing that a greater level of CSO control is not feasible are the same as those that allow removal of a use that is not an existing use, a partial use designation, or a variance. It must be demonstrated that at least one of six specific conditions exists. In general terms, these conditions include: impacts from naturally occurring pollutant concentrations; natural or low flow conditions; natural physical conditions; hydrologic modifications; human caused conditions, which can not be remedied or would cause more environmental damage to correct; or demonstration of substantial and widespread economic and social impact.

DEP's new policy states that generally eligibility for Class B(CSO) status is limited to discharges which can meet water quality standards more than 95 percent of the time, but the highest level of control must always be achieved for each case as determined in the facilities plan through a cost/benefit analysis. Priority will be given to relocating or eliminating CSOs in sensitive areas such as outstanding resource waters, bathing areas, water supply intakes, endangered species habitat, and shellfish beds. It is DEP's responsibility to prepare a Use Attainability Analysis (UAA), based on the facilities plan, to document that achieving a higher level of CSO control is not feasible or appropriate.

Variance. A variance provision added to the state's water quality standards allows short-term modification of the water quality standards in permits when interim control measures or further studies are appropriate. A variance will be used where long-term attainability of the standard is uncertain, the CSO abatement plan includes phased implementation, and/or DEP believes the standard may ultimately be attained. Unlike a "partial use" designation, a variance would be both discharger and pollutant specific, time-limited, and would not change the currently designated waterbody uses (Class B or Class SB). A variance would allow CSO discharges to be in compliance with "modified" water quality standards in the NPDES permit while additional analyses are conducted and progress is made toward meeting the existing standard.

Variance procedures involve the same substantive requirements that apply to a B(CSO) designation; but since variances maintain the currently designated uses, a formal UAA is not required. DEP intends to use the NPDES permit as the vehicle to grant the variance. Public notice of the permit will clearly state that the variance temporarily modifies the state's water quality standards. Variances will normally be reviewed every three years, and if deemed necessary may be codified in the water quality standards at the required triennial standards review. The regulations allow a variance under the same conditions as a Class B(CSO) classification or a partial use designation, as listed above.

Partial Use Designation. In receiving water segments where DEP is certain that designated uses or standards can not, and will not, be attained on a permanent basis during intermittent storm events, a partial use designation will be granted for specific segments through a regulatory revision, following a UAA. The UAA will assess physical, chemical, biological, and economic factors affecting beneficial uses. The analysis also will evaluate whether a designated use could be attained if CSO controls were implemented, or if background conditions or non-CSO sources would preclude uses even if CSOs were completely eliminated. Partial use is the term used to describe waters occasionally subject to short-term impairment of uses, but which generally support those uses. Generally, short-term impairment means that the standards are met at least 75 percent of the time, but DEP will determine the permissible level through the facilities planning process on a case-by-case basis. Partial use can be defined by seasons or a particular storm event when a use such as swimming will be unattainable in CSO-impacted waters. The use must be fully protected downstream, in other seasons, or during smaller storm events.

DEP may find that a permittee has demonstrated that a use is not attainable under circumstances identified in the regulations. Information to support a designation will be developed largely in the facilities plan or environmental impact report. The information contained in the facilities plan and available watershed plans will include most information necessary for the UAA, which must be submitted to EPA prior to the designation.

Change in Classification. Where designated uses can not and will not be met on a permanent and constant basis in the foreseeable future, DEP will consider a change in classification from Class B (or SB) to Class C (or SC) to be appropriate, though this will be the option of last resort. As with a partial use designation, a UAA will be required for a change in classification.

Development of MWRA CSO Control Plan

MWRA's long-term control plan was developed for CSOs that are located in Boston, Cambridge, Somerville, and Chelsea. These CSOs impact Boston Harbor and its major tributaries, including the Charles River. Because of the diversity of the watersheds tributary to the CSO receiving waters throughout the study area and their geographical separation, major waterbodies were divided into 14 receiving water segments. Each segment had distinct characteristics and specific water quality issues to be addressed. Together, the segments support a spectrum of uses that range from bathing beaches and recreational areas to shipping channels and other industrial operations.

As with EPA's 1994 national CSO policy, demonstrating compliance with DEP's CSO policy involved fulfilling the requirements of a CSO control planning process. The process required MWRA to cover nine elements in developing its long-term CSO control plan, including system characterization, monitoring, and modeling; maximizing flows to the central treatment plant, evaluation of a full range of control alternatives, and cost/performance analyses. Consistent with the *demonstration approach* in EPA's policy, compliance with water quality standards to protect designated uses was confirmed through the CSO control planning process.

The demonstration approach involved detailed assessments of receiving waters and the impacts of CSO discharges and other sources of wet weather pollutants on water quality. The MWRA CSO control plan was developed using the demonstration approach because sufficient data on CSO and non-CSO sources of pollution and corresponding water quality impacts were available and were considered in determining appropriate controls on a site-specific basis. If standards or uses could not be met due to background conditions or pollution sources other than CSOs, it was shown that remaining CSO discharges would not preclude attainment of water quality standards if other sources were controlled. In general, the planned control program demonstrated that the maximum pollution reduction benefits reasonably attainable would be provided.

Water Quality Evaluations

Receiving water quality models were developed and applied to compare the performance of varying levels of CSO control to baseline conditions in the receiving waters. Tabular presentations were used to compare predicted hours of violations of the state water quality standards for swimming and boating. Hours of violation were compared for baseline conditions, baseline conditions for non-CSO pollutant sources only (stormwater, dry weather, boundary conditions), the recommended plan, and the recommended plan considering CSO sources only.

The annual percent compliance with the bacteria standard for swimming (200 colonies per 100 milliliters) was calculated to estimate the impact that the remaining untreated CSO discharges would have on water quality. For each receiving water segment, the frequency and volume of untreated CSO discharges remaining in the typical rainfall year were determined using an annual model simulation. Hours of violation associated with each untreated discharge event were conservatively assigned based on the hours of violation associated with the 1-year, 24-hour storm. This methodology was used to calculate the range of percent compliance (based on all sources and CSO-only sources) with the bacteria standard for swimming for all receiving water segments which will continue to have untreated CSO discharges following implementation of the CSO control plan.

RESULTS

Table 2 presents the hours of violation of the fecal coliform bacteria standards for swimming and boating from the 3-month, 24-hour storm for baseline conditions and for the recommended plan. For all of the receiving water segments, the hours of violation after implementation of the recommended plan due to CSO-only discharges is zero for both the swimming and the boating standards. Violations would occur in the Charles River and Alewife Brook, if dry weather sources of fecal coliform bacteria were considered. Comparing the "recommended plan CSO-only" results to the "baseline conditions non-CSO only" results, it is clear that the violations of the bacteria standards remaining after implementation of the recommended plan will be caused by the impacts of non-CSO sources.

As an example, Table 3 summarizes the information used to calculate the annual percent compliance for the Upper Inner Harbor receiving water segment. Under the recommended plan, five storms in the typical year will cause overflows to occur from at least one of the four CSO outfalls discharging to the segment. The total overflow volume for each storm was compared to the volume discharged from the outfalls in the 3-month and 1-year, 24-hour storms. Under the recommended plan, none of the outfalls discharges during the 3-month storm and only two outfalls discharge during the 1-year storm. In the typical year, the volume of CSO discharged during two of the five storms is relatively insignificant, while the volume for each of the other three storms is comparable to the 1-year, 24-hour storm.

For CSO-only discharges, the bacteria standard for swimming is not predicted to be exceeded in the Upper Inner Harbor during the 3-month, 24-hour storm, but is predicted to be exceeded for 8 hours during the 1-year, 24-hour storm. Conservatively assuming that all five storms in the typical year would cause 8 hours of violation, the total number of hours in the typical year that the swimming standard would be violated due to CSO discharges equaled 40 hours. This means that on an annual basis, the swimming standard would be met 99.5 percent of the time. Even assuming that there would be 17 hours of violation per storm based on all sources of pollutants, the compliance is still 99.0 percent.

TABLE 2. HOURS OF VIOLATION OF BACTERIA STANDARDS FOR 3-MONTH, 24-HOUR STORM (based on 96-hour simulation)

Receiving Water Segment	Hours of Violation of Swimming/Boating Standards[1] for Fecal Coliform			
	Baseline Conditions[2] (all sources)	Baseline Conditions (non-CSO only)	Recommended Plan[2] (all sources)	Recommended Plan (CSO only)
North Dorchester Bay	13 / 0	5 / 0	0 / 0	0 / 0
South Dorchester Bay	11 / 0	11 / 0	13 / 0	0 / 0
Neponset River	72 / 35	72 / 35	72 / 36	0 /0
Constitution Beach	25 / 0	24 / 0	25 / 0	0 / 0
Upper Charles River	96 / 86	96 / 86	96 / 86	0 / 0
Lower Charles River[3]	86 / 36	86 / 36	86 / 40	0 / 0
Alewife Brook	96 / 88	96 / 88	96 / 88	0 / 0
Upper Mystic River	88 / 56	88 / 56	88 / 56	0 / 0
Upper Inner Harbor	28 / 0	0 / 0	0 / 0	0 / 0
Lower Inner Harbor	14 / 0	0 / 0	0 / 0	0 / 0
Mystic/Chelsea Confluence	45 / 0	45 / 0	45 / 0	0 / 0
Reserved Channel	24 / 4	0 / 0	0 / 0	0 / 0
Fort Point Channel	45 / 31	27 / 0	28 / 0	0 / 0

(1) Swimming standard = 200 # / 100 ml; Boating standard = 1000 # / 100 ml.
(2) Includes boundary, stormwater, dry weather, and CSO sources.
(3) Includes Back Bay Fens.

The hours of violation for the 1-year, 24-hour storm and annual percent compliance for all receiving water segments is shown in Table 4. The annual percent compliance, even using the extreme case based on hours of violation caused by all sources in the 1-year, 24-hour storm, is greater than 95 percent in all receiving water segments. Using hours of violation based on CSO-only sources for the 1-year, 24-hour storm, the compliance for all segments is greater than 98 percent. The annual percent compliance calculations demonstrate compliance with DEP's requirements for B(CSO) or SB(CSO) designations for minimally-impacted receiving waters. It should be noted that the upper end of the range of percent compliance for the Charles River and Alewife Brook receiving water segments is based on model results, assuming no dry weather fecal coliform bacteria contributions. If dry weather sources were included, the bacteria standard for swimming would be violated all of the time.

TABLE 3. BASIS FOR WATER QUALITY COMPLIANCE
UPPER INNER HARBOR

Outfall	Typical Year Storm Volume (MG)					
	5/3	6/1	9/24	9/27	10/24	Total Volume
BOS009	0.06	0.01	0.23	0.02	0.29	0.61
BOS012	–	–	–		0.01	0.01
BOS019	–	0.26	0.32		–	0.58
BOS057	–	–	–		0.43	0.43
Total	0.06	0.27	0.55	0.02	0.73	1.63

Outfall	Design Storm Volume (MG)	
	3 mos.	1 yr.
BOS009	–	0.24
BOS012	–	–
BOS019	–	0.29
BOS057	–	–
Total	0	0.53

Fecal Coliform Standard	Hours of Violation - Recommended Plan			
	3 mo.		1 yr.	
	All Sources[1]	CSO only[2]	All Sources[1]	CSO only[2]
>200	0	0	17	8
>1000	0	0	0	0

CSO only: 5 storms @ 8 hours = 40 hours ➪ 99.5%
All sources: 5 storms @ 17 hours = 85 hours ➪ 99.0%

[1] Includes boundary, stormwater, dry weather, and CSO sources
[2] Stormwater component excluded

DISCUSSION

MWRA's recommended CSO control plan will maximize capture of combined sewage flow and provide treatment at its Deer Island treatment plant or CSO treatment facilities for almost all of the total annual combined sewage volume. Implementation of the recommended plan will reduce the annual volume of untreated CSO discharges by 95 percent compared to baseline conditions. Of the annual CSO volume remaining after implementation of the recommended plan, 95 percent will be treated at MWRA CSO facilities prior to being discharged. When conveyance to the Deer Island treatment plant is considered, 99.7 percent of the total annual combined sewage volume will be captured and treated.

For receiving water segments where CSOs will continue to discharge, calculating annual percent compliance using all sources and CSO-only sources based on the combined system's response to the 1-year, 24-hour storm results in a realistic range of compliance that can be expected in a typical rainfall year. Most of the CSO discharges that will remain following implementation of the recommended CSO control plan are small volume, short duration occurrences which will cause very short-term receiving water impacts. In fact, under the recommended plan, all segments will be more significantly impacted by dry weather conditions, upstream or boundary conditions, and stormwater discharges than by the remaining CSO discharges. Therefore, CSO discharges remaining after implementation of the recommended plan will not preclude attainment of water quality standards or designated uses.

TABLE 4. HOURS OF VIOLATION OF BACTERIA STANDARDS FOR 1-YEAR, 24-HOUR STORM (based on 96-hour simulation)

Receiving Water Segment	Hours of Violation of Swimming/Boating Standards(1) for Fecal Coliform				Annual Compliance % All sources vs CSO only
	Baseline Conditions(2) (all sources)	Baseline (non-CSO only)	Recommend Plan(2) (all sources)	Recommend Plan (CSO only)	
North Dorchester Bay	20 / 6	16 / 0	0 / 0	0 / 0	100(4)
South Dorchester Bay	17 / 0	17 / 0	23 / 0	0 / 0	100(4)
Neponset River	71 / 35	68 / 33	70 / 33	0 / 0	100(4)
Constitution Beach	27 / 3	27 / 1	27 / 1	0 / 0	100(4)
Upper Charles River	96 / 84	96 / 84	96 / 84	0 / 0	98.9 - 100(5)
Lower Charles River(3)	88 / 56	88 / 50	88 / 56	0 / 0	98.0 -100(5)
Alewife Brook	96 / 90	96 / 90	96 / 90	0 / 0	95.6 - 100(5)
Upper Mystic River	90 / 70	90 / 60	90 / 64	0 / 0	100(6)
Upper Inner Harbor	37 / 14	7 / 0	17 / 0	8 / 0	99.0 - 99.5
Lower Inner Harbor	28 / 0	0 / 0	8 / 0	0 / 0	99.6 - 100
Mystic/Chelsea	50 / 17	49 / 16	49 / 15	0 / 0	97.8 - 100
Reserved Channel	30 / 16	0 / 0	0 / 0	0 / 0	100(6)
Fort Point Channel	48 / 34	29 / 14	33 / 18	25 / 13	98.5 - 98.9

(1) Swimming standard = 200 # / 100 ml; Boating standard = 1000 # / 100 ml.
(2) Includes boundary, stormwater, dry weather, and CSO sources.
(3) Includes Back Bay Fens.
(4) CSO discharges are eliminated.
(5) These segments violate the bacteria standard for swimming all the time if dry weather components are included.
(6) Treated discharges only.

MWRA's CSO control plan is one of the first plans to be reviewed under the new state CSO policy. The control plan provides justification for its recommendations for (1) maintaining Class B or SB designations in the most sensitive receiving waters that support critical uses (swimming, shellfishing) by eliminating CSO discharges, (2) making Class B(CSO) and SB(CSO) designations in other receiving waters where compliance was demonstrated to be achieved at least 95 percent of the time, and (3) using a variance for the Charles River while more information on impacts from non-CSO sources can be obtained through on-going watershed planning investigations. Table 5 summarizes the water quality classifications for the 14 receiving water segments.

TABLE 5. DEP WATER QUALITY STANDARDS CLASSIFICATIONS

Receiving Water Segment	DEP WQS Designation	Major CSO Control Method(1)
North Dorchester Bay	SB	CSO Relocation
South Dorchester Bay	SB	Sewer Separation
Neponset River	B	Sewer Separation
Constitution Beach	SB	Sewer Separation
Upper Charles River	Variance	Hydraulic Relief
Lower Charles River	Variance	Sewer Separation/Upgrade Treatment
Back Bay Fens	B(CSO)	Sewer Separation
Alewife Brook	Variance(2)	Partial Sewer Separation
Upper Mystic River	Variance(3)	Upgrade Treatment
Upper Inner Harbor	SB(CSO)	Interceptor Relief/ Storage/Upgrade Treatment
Lower Inner Harbor	SB(CSO)	Interceptor Relief
Mystic/Chelsea Confluence	SB(CSO)	Hydraulic Relief/ Interceptor Relief/Upgrade Treatment
Reserved Channel	SB(CSO)	Storage/Treatment
Fort Point Channel	SB(CSO)	Storage/Treatment

(1) Plan may contain additional controls.
(2) Originally proposed as B(CSO) under MWRA's recommended plan.
(3) Originally proposed as SB(CSO) under MWRA's recommended plan.

DEP found MWRA's recommended CSO control plan to be adequate to support its administrative determinations on CSO-impacted waters and prepared a UAA based on the information MWRA provided. In making its final determinations, DEP carefully considered comments submitted on its tentative decisions for waterbody classifications that underwent public review. Based on public comments, DEP's administrative determinations included MWRA's proposed waterbody classifications except in two instances, where variances were determined to be more appropriate for the Alewife Brook and the Upper Mystic River. DEP agreed with comments stating that more information on causes of water quality violations in these waterbodies should be obtained before changes to water quality standards for CSO-impacted designations are made.

In waters that will continue to be affected by CSOs, DEP's UAA confirmed its determinations that higher levels of CSO control, beyond those recommended by MWRA, were not feasible based on current information. DEP concurred with the cost/benefit analyses in MWRA's plan that showed that the cost for higher levels of control would not yield improved attainment of designated uses. According to its CSO policy, DEP deemed that MWRA's plan demonstrated that more stringent controls would result in "substantial and widespread economic and social impact."

CONCLUSIONS

DEP responded to EPA's new national CSO policy by developing a state policy and regulatory revisions that allow flexibility in developing CSO control plans and demonstrating compliance with water quality standards. DEP's new policy and regulatory revisions reflect the agency's understanding of the realities of wet weather events and the nature of their impacts on receiving waters. The creation of the Class B (CSO) water quality standard provides the regulatory flexibility to acknowledge potential short-term excursions from Class B criteria, resulting from extreme and infrequent storm event conditions, without downgrading water quality standards.

The MWRA prepared its CSO control plan in conformance with DEP's planning requirements and demonstrated compliance with state water quality standards. DEP prepared a UAA that confirmed its approval of MWRA's recommended CSO control plan. DEP's administrative determinations on waterbody classifications included the classifications proposed in MWRA's plan, except in two instances where variances were determined to be more appropriate. EPA has concurred with DEP's UAA and administrative determinations, thereby approving the changes in state water quality standards.

For over five years, MWRA and DEP cooperated in a comprehensive CSO planning process and a regulatory revisions process, both of which involved extensive public review and comment. The joint processes have resulted in an approved CSO control plan which will meet water quality standards and protect designated uses. The coordinated effort undertaken by MWRA and DEP is a successful example of how to effectively regulate CSOs and achieve water quality improvements.

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The Doan Brook Watershed Plan Progress Report: Development of an Effective Quality Assurance Project Plan

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ABSTRACT

Doan Brook serves the cities of Beachwood, Cleveland, Cleveland Heights, Shaker Heights, and University Heights. The watercourse is about 9.4 miles in length and discharges into Lake Erie. The total drainage area is approximately 20 square miles and is comprised of primarily of low-density urban land-use with some institutional and commercial land-use in the lower and middle sections of the watershed. Open spaces, parks, and conservation areas are closely linked to the watercourse.

During wet-weather, a number of combined sewer overflows discharge into Doan Brook and historical water quality and flooding problems are well documented. In order to improve water quality, reduce erosion and flooding problems, and enhance the aquatic habitat of Doan Brook, the Northeast Ohio Regional Sewer District has embarked on a comprehensive watershed investigation. This paper provides a discussion of the development of the water quality monitoring program associated with this investigation and provides a progress report on the early stages of the field program.

The defensibility of the data collected throughout the course of the project represents an important consideration. Therefore, rigorous quality control and quality assurance measures are built into the monitoring program. A comprehensive Quality Assurance Project Plan, or QAPP, was developed for the water quality monitoring program. In support of this effort, appropriate data quality objectives, or DQO's, were developed through a systematic evaluation of the project goals and objectives. An overview of the QAPP development process is provided in this paper. Also, this paper describes how various computer models are going to be used to analyze alternative control options.

KEYWORDS

quality assurance, quality control, wet-weather, monitoring, stormwater, receiving water

INTRODUCTION

Background

During wet-weather, a number of combined sewer overflows discharge into Doan Brook and contribute to water quality and flooding problems. Currently there are 16 combined sewer overflows (CSO's) that discharge into Doan Brook in wet-weather.

There are documented water quality and flooding problems along Doan Brook. Available data shows that there is bacteriological contamination during dry and wet-weather at various locations. Previous surveys of macroinvertebrate communities along Doan Brook indicate poor-quality habitat that is probably due to organic pollution sources. These conditions point to the need for a CSO facilities plan, as well as storm water control facilities, to control discharges to the Brook. The Doan Brook Watershed Study was designed to fulfill this need, as well as to further the community's goal of restoring Doan Brook and Shaker Lakes as assets to the community.

This paper focuses on a fundamental component of this watershed study: the development and implementation of an effective monitoring program. The design of the monitoring program and the development of the quality control procedures supporting the fieldwork are discussed in this paper. Unfortunately, at the time of publication, only limited amount of water quality information from the ongoing

1998 program was available. It is anticipated that preliminary field measurements for dry and wet-weather will be available for the conference presentation of this paper.

Since this investigation was partly funded by an EPA grant, a comprehensive Quality Assurance Project Plan, or QAPP, was required in support of the monitoring program. The relationship between the QAPP, and other quality control documents such as Standard Operating Procedures, Field Monitoring and Sampling Plan, and Data Quality Objectives are outlined in this paper. As a result of the rigorous quality control and quality assurance procedures built into the monitoring program, the data collection efforts will yield high-quality and defensible information that will ultimately provide a solid framework for the final watershed and facilities plans.

The monitoring program was organized into four major categories:

- Flow Monitoring: A flow monitoring program was required for major sewers, sources, and streams.
- Source Monitoring: An assessment of source pollutant loads from combined sewer overflows, storm sewers, and mixed sewer systems was necessary.
- Stream Monitoring: A sediment and water quality program was necessary to assess stream conditions in wet and dry weather.
- Lake Monitoring: A sediment and water quality program was necessary to assess the characteristics of the Shaker Lakes and other impoundment:

Specifically, the monitoring program was designed to support:

- The determination of existing water quality in Doan Brook.
- Comparisons of the water quality of Doan Brook with appropriate water quality regulations.
- The development of stream water-quality and hydraulic models to be used for facilities and watershed planning.
- The estimation of seasonal and annual pollutant loadings for input into a Lake Erie water quality model.
- The definition of water quality and hydraulic relationships between Doan Brook, the Shaker Lakes and Lake Erie.

Study Area

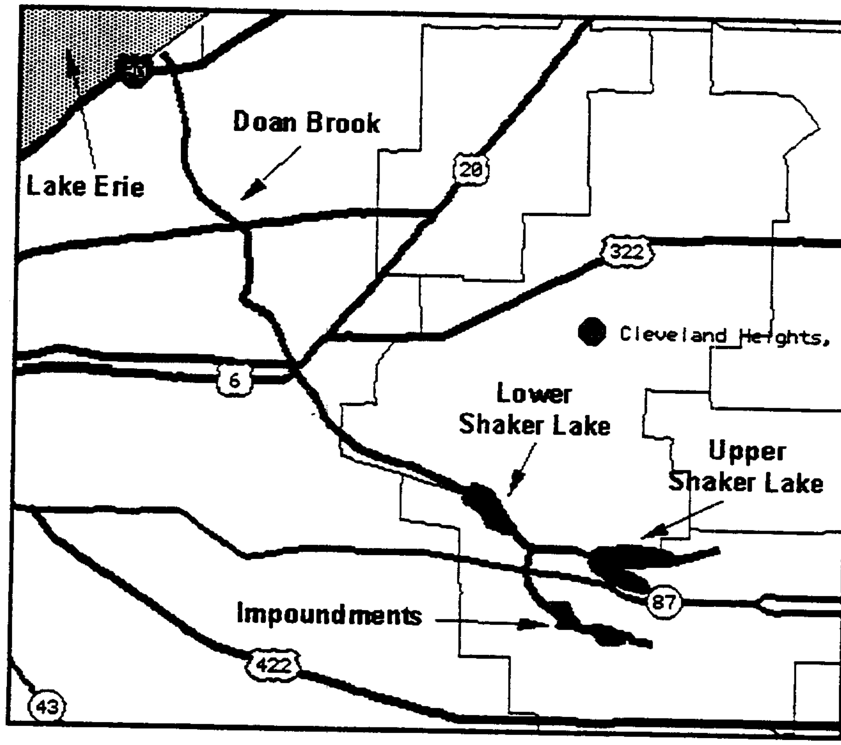
Doan Brook flows through the cities of Beachwood, Cleveland, Cleveland Heights and Shaker Heights. The watercourse is about 9.4 miles in length and discharges into Lake Erie. The total drainage area is approximately 20 square miles and is comprised of primarily low-density urban, institutional and commercial land-use. Open spaces, parks, and conservation areas are integral components of the watercourse. An illustration of the study area is provided in Figure 1.

Overview

This paper is organized into three major sections:

1. *Quality Assurance / Quality Control Planning*: This section provides an overview of the QA/QC planning process and a brief description of the field-monitoring program.
2. *Preliminary Field Measurements*: Initial field measurements of water quality of Doan Brook during dry and wet-weather is presented in this section. Since the field program has recently been initiated, only a limited amount of field information is available.
3. *Summary*: A brief summary of the QA/QC process and preliminary field measurements.

Figure 1. Doan Brook Study Area



QUALITY ASSURANCE / QUALITY CONTROL PLANNING

Since this Doan Brook Watershed Study is funded, in part, by an EPA grant, the defensibility of the data collected throughout the course of the project represents an important consideration. Therefore, rigorous quality control and quality assurance measures are built into the monitoring program. There are four major categories to the quality assurance / quality control process:

1. Data Quality Objectives, or DQO's,
2. Quality Assurance Project Plan, or QAPP.
3. Standard Operating Procedures, or SOP's,
4. Field Monitoring Plan, or FSP, and

A brief overview of the DQO, QAPP, and DQO documents is provided below. The FMP provides detailed instructions for field personnel in terms of where and when to sample or obtain field measurements.

Data Quality Objectives (DQO's)

DQO's were established according to EPA guidelines (EPA, 1994). In general, data quality objectives are designed to match the desired quality of information collected with the intended application of the data. In this case, the data collected through the course of the study will serve as a basis for:

- A datum of existing water quality conditions (to serve as a benchmark for future comparisons) and to allow for assessment of compliance with respect to Ohio water quality objectives.
- Calibration and verification of all hydraulic and water quality models.
- Development of facilities plan alternatives and preferred strategies.

- Development of a Doan Brook Watershed Plan.
- Integration with other water quality investigations in the Cleveland area.

Clearly the scope of the intended application is broad and as a consequence, the quality of the data collected must be relatively high. The systematic approach to determining appropriate DQO's involved:

1. Identification of all significant issues to be resolved in the study. For the Doan Brook Watershed Study issues focused on current status, pollution sources, receiving water impacts, watercourse flooding, erosion, control options and facilities planning.
2. Identification of what information is required to address each issue.
3. Identification of what parameters must be measured, where and when.
4. The development of a suitable approach to data collection that fits within various constraints of the project (time, budget, requirements of larger Easterly project).

As an illustrative example of the process, a summary of the issues surrounding current status and the information required is provided in Table 2. Similar analyses were completed for other relevant topics such as pollution sources, receiving water impacts, and watercourse flooding.

Table 2. Issues and Information Required for Evaluation Of Current Status

ISSUE	INFORMATION REQUIRED
• Is existing water quality in compliance with current regulatory standards?	• Measurements of water quality parameters for which there is a regulatory standard. Measurements needed at various locations along the system in order to gauge the impact of various inputs to the system. • Measurements needed in both dry and wet weather to account for temporal variability.
• How does existing sediment compare with available guidelines or scientific thresholds for protection of aquatic habitat and aquatic life?	• Measurements of sediment quality for parameters for which there is a regulatory standard or scientifically accepted standard or guideline. • Measurements needed at various locations along the system at which sediment deposition occurs. Multiple locations needed within the Shaker Lakes to account for spatial variability in sediment deposition patterns.
• What is the current biological state and quality (i.e. diversity and health of aquatic species) in the system? • What factors other than water and sediment quality may be affecting biological status?	• Sampling and inventory of macroinvertebrate populations at locations along the system, at same locations at which sediment and water quality are being sampled, to allow biological data to be correlated with sediment and water quality data. • Data are to be adequate to allow computation of accepted indices of aquatic habitat diversity, health and quality.
• What is the current trophic status of the Shaker Lakes and what inputs and processes are responsible for present conditions? • What are the effects of existing nutrient loadings on the lakes? • What is the rate of sediment accumulation within the lakes and what are the probable sources of sediment inputs?	• Measurements of biomass productivity, nutrient levels, water clarity, density stratification and water quality at various locations within each lake, to account for potential spatial variability. • Assessment of mixing conditions, using direct measurements and/or hydrodynamic computer modeling. • Measurement of lake bathymetry to provide information on lake depth, geometry and volume, and allow assessment of changes that have taken place over time due to sedimentation or other processes.

Table 3. Parameters of interest and General Approach to Data Collection for Surface Water Quality Of Current Status

PARAMETER	REQUIRED APPROACH TO DATA COLLECTION
Fecal coliform and *E. coli*	• A wet-weather sampling program is required to address stream water quality during and immediately following rainfall. Both spring frontal rainfall events and summer convective storms should be addressed. • A dry-weather sampling program is required to address water quality during extended dry-weather periods. • Regular sampling (regularly spaced through time) is required to address the expected seasonal variability in water quality along the watercourse, and expected variability in water column conditions within the Shaker Lakes.
Metals (Total Recoverable and Dissolved): Cd, Cu, Cr, Fe, Pb, Zn	
TSS, conductivity, hardness Dissolved oxygen and CBOD Nutrients (TP, SRP, TKN) Temperature, pH, Ammonia	

Standard Operating Procedures (SOP's)

SOP's were developed for every sampling or measurement task to be undertaken in the monitoring program. The SOP's were developed according to EPA guidelines and are presently under final review by EPA staff. Every task, from sewer flow monitoring to field instrument calibration, is provided with a SOP. In the case of sample collection, the individual SOP's provide detailed instructions regarding sample tracking and chain of custody. Furthermore, SOP's include procedures for data management and control, as well as detailed field protocols. A list of SOP's prepared for this investigation is presented in Table 1.

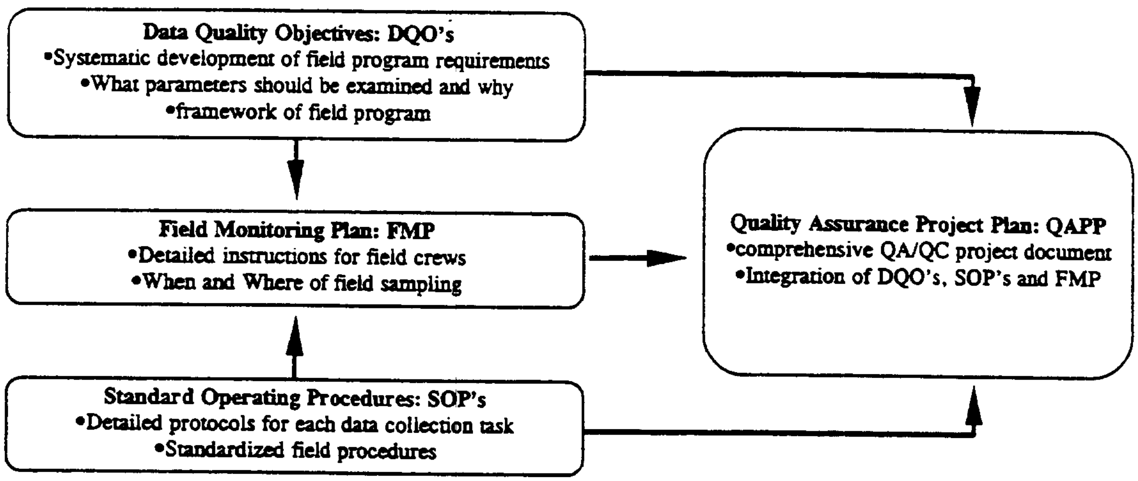
Table 1. Standard Operation Procedures Developed for The Doan Brook Watershed Study

SOP Number	SOP Title
1	Sample Bottle Preparation
2	Sewer Flow Monitoring
3	Stream Flow Monitoring and Gauging
4	Grab Sample Protocol
5	Automatic Sampling Protocol
6	Sediment Sampling Protocol
7	Macroinvertebrate Sampling Protocol
8	Quantitative Habitat Suitability Index Sampling Protocol
9	Lake Water Quality Monitoring
10	Aquatic Macrophyte Survey and Identification
11	Macroinvertebrate Identification and Enumeration
12	Field Instrument Calibration Methods
13	Analytical Procedures
14	Sediment Grain Size Analysis

Quality Assurance Project Plan (QAPP)

The QAPP document sets out detailed plan and procedures for meeting the data requirements defined in the DQO's. The QAPP incorporates a set of SOP's that provide field personnel with detailed instructions on individual sampling and monitoring tasks. THE FSP sets out the precise details of when and where sampling and monitoring are to Take place, including specific requirements regarding QA/QC (e.g. submission of duplicate samples, bottle blanks and field blanks). The linkages of the various documents are illustrated in Figure 2. The QAPP builds on the DQO document by defining detection limits, accuracy goals, and data volume targets for each parameter of interest. Furthermore, the QAPP provides an indication of the number of measurement replicates and the desired measurement precision.

Figure 2. Project QA/QC Documents

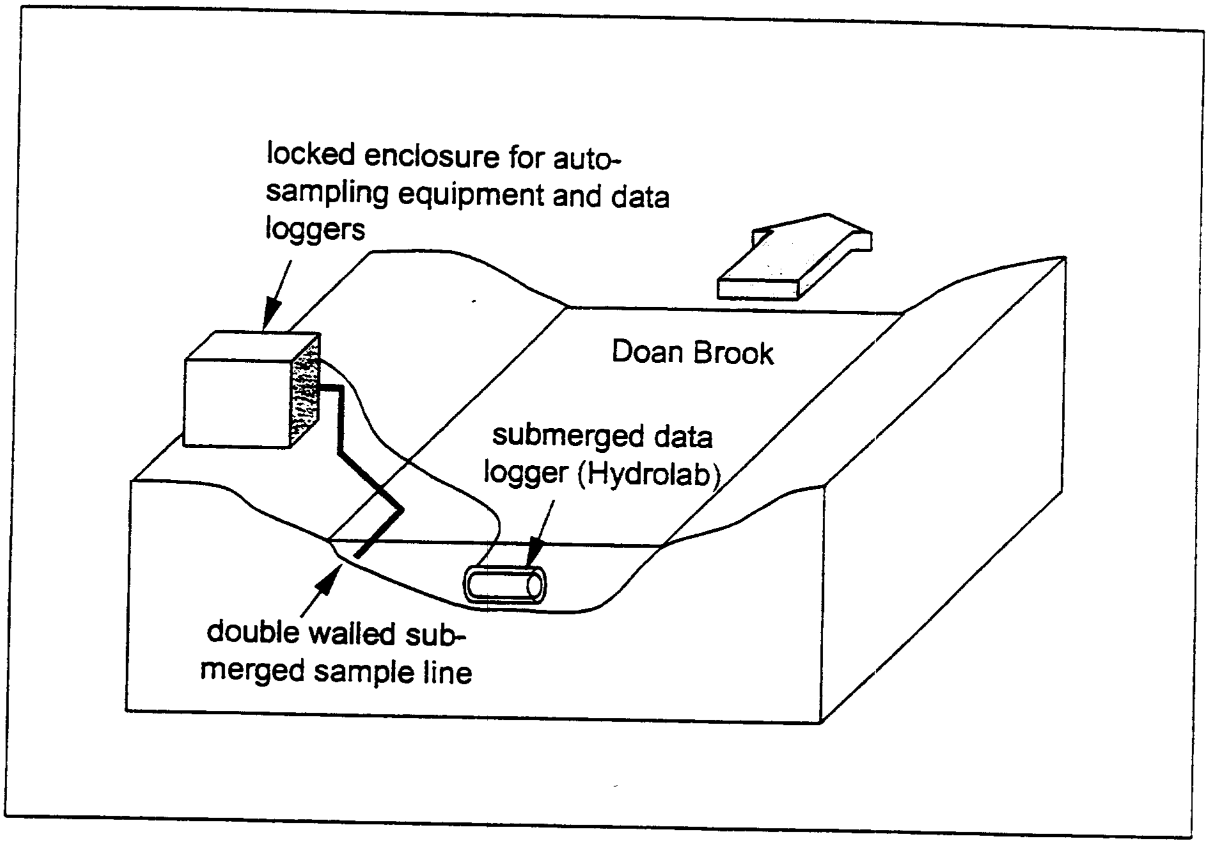


PRELIMINARY RESULTS OF THE FIELD PROGRAM

The field program includes monitoring of sources, Doan Brook, and associated lakes and impoundments. At the time this paper was prepared, no water quality or sediment quality analysis results were available. However, a limited amount of water quality information from in-stream data-loggers (Hydrolab instrumentation) was available. A typical data logger installation is illustrated in Figure 3. This particular monitoring site is near the confluence of the Doan Brook and Lake Erie and is referred as Site 1. Field observations indicate that Site 1 is immediately upstream of normal backwater conditions and water velocity at Site 1 is normally low.

Example monitoring data from Site 1 is provided in Figures 4 and 5. A continuous plot of dissolved oxygen (expressed as an estimate of percent saturation), and temperature is provided in Figure 4, while Figure 5 provides a continuous plot of conductivity and temperature. The dissolved oxygen measurements are preliminary unverified data and the final review has not been completed. Both Figures 4 and 5 cover a monitoring period starting at 16:00 on April 1, 1998 and ending at 15:00 on April 10, 1998.

Approximately 1.5 inches of rain fell on the study area on April 8 and 9, 1998. The impact of this rainfall, in terms of dissolved oxygen and conductivity changes is evident in the plots. As Figure 4 illustrates, the regular diurnal dissolved oxygen cycle is interrupted following the rainfall event. A prolonged period of relatively low dissolved oxygen occurs during and immediately following the rainfall event. In dry-weather, for example form April 1, 1998 through April 6, 1998, the dissolved oxygen rises to super-saturated conditions during the mid-afternoon and drops to below saturation during the night hours. This diurnal cycle is probably due to aquatic plant and algae photosynthesis and respiration. Similar diurnal patterns have been observed in other, low-velocity, nutrient enriched, river systems (Hulley *et al*, 1996).



The relatively low velocity during and after the rainfall event is presumably a result of wet-weather pollutant loads. However, this conclusion has not been confirmed with direct measurements of biochemical oxygen demand.

The conductivity measurements at Site 1 indicate that during dry-weather there is no significant diurnal variability, however, during and following the rainfall, the conductivity drops from about 1700 uS/cm to less than 1000 uS/cm. Presumably the reduction is a result of dilution since the conductivity of CSO inflow and overland runoff is less than ambient in-stream conductivity.

The results presented in Figures 4 and 5 are preliminary and have not been subject to the required quality control review process. Although the absolute values of water quality parameters, such as dissolved oxygen and conductivity, may be adjusted in the final data review, the dry and wet-weather trends illustrated in the Figures provide an indication of wet-weather impacts.

WET WEATHER POLLUTION EFFECTS ON WATER QUALITY IN CRUM CREEK

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ABSTRACT

The Crum Creek, running through suburbs west of Philadelphia, shows impacts of wet weather pollution on the health of the stream. The creek is used for water supply and recreation, and it supports wildlife. Significant oxygen deficits have been measured in the creek by volunteer monitors. This paper reports results from an intensive monitoring project on a section of the creek near Swarthmore College to further characterize this problem, and to investigate its causes. Factors found to influence oxygen deficit include elevated BOD in the water column following rainfall events and sediment oxygen demand exerted in pools along the creek. The elevated BOD levels during rain may also be caused by landfill leachate, animal waste, and untreated human waste from leaking sewers. Transient variations in conductivity and turbidity were measured by an electronic sonde during rainfall events. These measurements suggest the existence of a two-part process during the first three hours of runoff: a dissolved solids flush followed by a suspended solids flush.

KEYWORDS

Dissolved oxygen, oxygen deficit, BOD, conductivity, turbidity, runoff, urban stream

INTRODUCTION

The focus of this paper is Crum Creek, a suburban stream west of Philadelphia, in Delaware County, Pennsylvania. The creek is approximately 100 km (~62 miles) long with a drainage basin of 99 km^2 and an average flow of 0.71 m^3/s (DuPolt, 1983). Its headwaters are formed in part by runoff from the town of Paoli, Pennsylvania, and it discharges into the Delaware Estuary in the City of Chester, Pennsylvania. It has one major reservoir, the Geist (Springton) Reservoir, which is operated by the Philadelphia Suburban Water Company (PSWCo). This investor owned utility company supplies drinking water to the northern and western suburbs of Philadelphia. There is a small intake pond downstream from the reservoir at PSWCo's treatment plant and pumping station. All of our monitoring activities on the creek have been carried out within a 2.4 km (1.5 mile) stretch from a point just below the treatment plant to a point just below the Swarthmore College campus.

Just downstream from the treatment plant intake, the creek flows through a county park (Smedley Park) which is used extensively for recreation. Also, the creek is fed by small tributaries that drain a country club, golf course, and the parking lots of a large shopping mall and another major shopping center containing a popular multi-theater cinema complex. A closed landfill in Springfield Township, has a permitted leachate discharge into another tributary which joins the creek in the park. A paper mill was operated during the first half of this century on land just above Smedley Park in an oxbow of the creek. Discharges from the settling ponds of this mill probably contributed significantly in the past to organic sediments, which may still add to the sediment oxygen demand.

Interstate 476, which connects Interstate 95 to the Pennsylvania Turnpike was constructed above the creek bed during 1989 - 1990. The highway crosses over the creek in several places. The construction caused significant sediment runoff into the creek, and now there is potential for runoff carrying gasoline, oil, and, during icy weather, road salt into the creek from many storm sewers that discharge into the creek. The highway serves commuters in the Philadelphia metropolitan area, and a great deal of interstate travel, including large trucks. It frequently experiences lengthy back-ups with traffic coming to a complete stop during peak hours.

Significant oxygen deficits at various points on the stream have been observed during the past seven years through the water quality monitoring activities of a volunteer monitoring organization, the Crum-Ridley-Chester Monitors and an affiliated student group at Swarthmore College called the Crum Creek Monitoring Project (McGarity, 1997). Our program of intensive monitoring on the creek during the summer, fall, and early winter of 1997 has helped to characterize the patterns of and effects on dissolved oxygen levels in the creek, including those caused by wet weather pollution.

METHODOLOGY

During the summer of 1997, data were taken daily at three sites that we call A, B, & C on Crum Creek where it passes through the Swarthmore College campus. The readings included DO (dissolved oxygen), temperature, percent oxygen saturation, BOD (biochemical oxygen demand), water height over a stationary sewer pipe (for flow measurements), and, occasionally, E.coli. During the fall of 1997, weekly measurements of the same parameters were taken at the A, B, & C sites as well as three sites at the landfill leachate discharge in Smedley Park. The park sites are: (U) upstream from the leachate discharge, (L) in a small tributary containing the leachate, and (D) downstream of the leachate discharge. An electronic sonde collected data at site B on oxygen concentrations, temperature, conductivity, and turbidity at 15 minute intervals for thirty five days during December, 1997 and January, 1998. On 12 December, 1997, a "creek walk" was taken to obtain a one-day profile of dissolved oxygen at many additional points along the entire section of the creek involved in our monitoring studies.

Specific Tests

- Dissolved oxygen measurements were taken using a variety of methods, in order to ensure correct calibration of each method. A DO meter (Yellow Springs Instruments model 55) was used regularly, and checked with periodical Winkler titration method DO tests.
- Biochemical oxygen demand tests were performed by filling a 300 mL BOD bottle with sample water and incubating at 20°C for 5 days.
- E.Coli measurements were obtained by collecting samples with Whirl-Pak bags, diluting the samples properly to multiple dilutions, filtering the dilutions and incubating them at 35 degrees Celsius for 24 hours in "m-coli blue" broth from Hach Company.
- The sonde is a Yellow Springs Instruments 6000 multiprobe instrument which took automatic readings of dissolved oxygen, temperature, conductivity, and turbidity. The data were stored in the sonde's internal memory. The sonde was deployed at approximately the midpoint of the water column, at a depth of about 0.46 m (1.5 feet) and about 0.46 m above the stream bottom.

RESULTS

Dry Weather Dissolved Oxygen Profiles

During normal, dry weather flow conditions, oxygen deficits occur downstream from slow moving pools, which occur frequently in the creek. The drop in dissolved oxygen may also be caused by sediment oxygen demand present mainly in the pools. Riffle areas and algae help to replenish oxygen in the water. Figure 1 and Table 1 show data from sites A, B, and C which demonstrate this "pool sag" effect. Site A is above a long pool, site B is below this pool and above a riffle, and site C is below the riffle. Data from all of our readings of DO, percent DO saturation, and temperature were combined to produce the statistical analysis shown in Figure 1. The box plots show the average deficits (the line inside the box), and the ranges of variation in the deficits. In Table 1, which shows the average changes in deficit across the pool and the riffle, data from the summer and fall are separated to show seasonal differences.

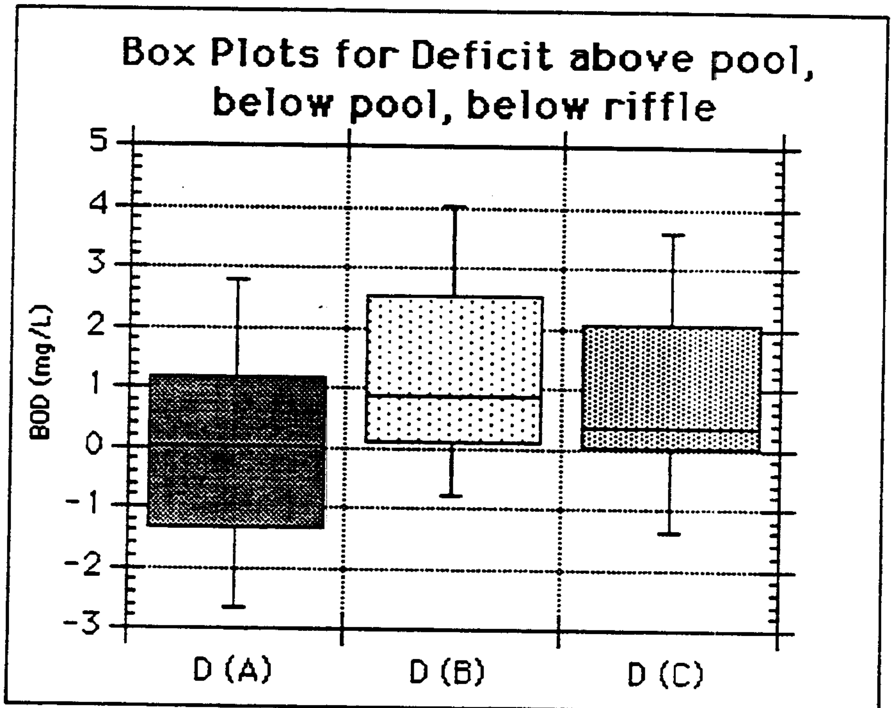

Figure 1. Deficit (D) above pool (A), below pool (B), and below riffle (C), for all measurements

Table 1. Differences in deficit across the pool and riffle	Average increase in deficit through pool (mg/L)	Average decrease in deficit through riffle (mg/L)
Both seasons	1.33	0.50
Summer	1.40	0.46
Fall	1.04	0.61

The "Creek Walk" graph (Figure 2) shows a profile of the DO, deficit, and temperature of the Crum Creek over a 1.5 mile stretch, on one day in mid-December, 1997. Again, the pools contribute to an increase in deficit and the riffles reaerate the water. The areas at sites 33-35, 24U-26, and 1-5 are clear examples of deficit increase along pools. There is also a trend of rising deficit between sites 13 and 23, interrupted only by the confluence with an oxygen-rich tributary named Whisky Run. The areas especially showing riffle effects are 23-24U, and 5-13. The presence of algae, observed in the last riffle, is likely contributing to the supersaturation found at the end of that riffle.

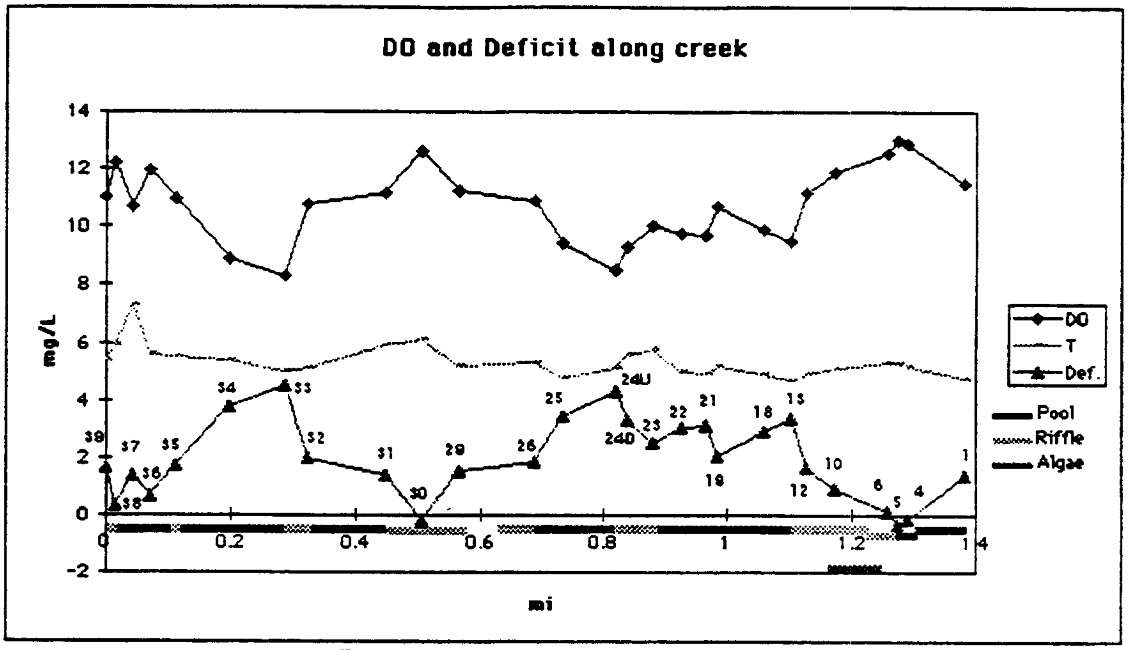

Figure 2. Creek Walk Profile (12/12/97)

Wet Weather Effects on BOD

Measurements of BOD indicate a strong correlation between BOD and rainfall. During dry weather, the ultimate BOD (calculated from the 5-day BOD measurements) at all six sites (A, B, C, U, L, and D) are in the range from 2 to 4 mg/L. However, on days with significant rainfall, the BOD increased. Figure 3 shows ultimate BOD (in mg/L) on the vertical axis with daily rainfall amounts on the horizontal axis. Rainfall was recorded at the Philadelphia International Airport, which is only about ten miles away from the monitored sites (National Oceanic and Atmospheric Administration, 1998).

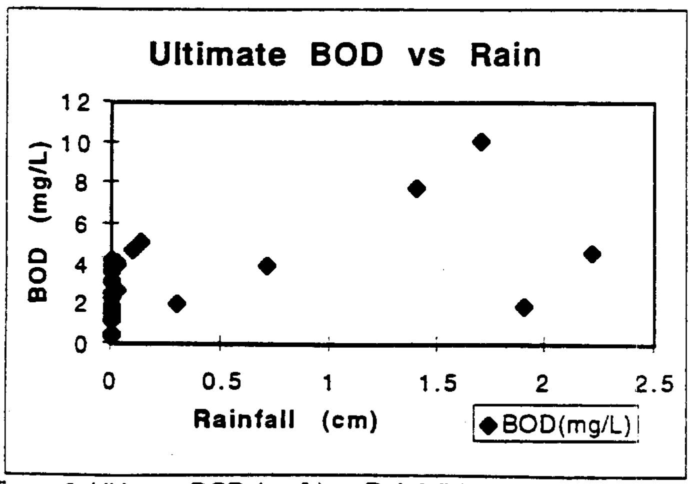

Figure 3. Ultimate BOD (mg/L) vs Rainfall (daily values at airport)
for both Summer and Fall

A possible source of BOD is leachate from the closed landfill, so the leachate was monitored for both BOD and DO. It turned out that the water flowing from the landfill into the creek had significantly higher dissolved oxygen concentrations than the rest of the creek, and during dry weather, the BOD in the leachate was lower than the BOD in the creek upstream of the discharge. However, after a two-day period of rain, the BOD in the landfill leachate was recorded as significantly higher than that in the creek. So, the landfill leachate is probably one source of the wet weather BOD increase in the creek.

In order to further determine the source of BOD, the relationship between BOD and E.Coli is analyzed. Since E.Coli is an indicator of human and animal waste, increases in BOD occurring with increases of E.Coli would show that some of the BOD may be coming from such waste. E.Coli does increase during rain, as seen in Figures 4 and 5 which show how the E. Coli count increases with streamflow. If the one extremely high E. Coli count (more than 10,000 colonies per 100 mL) is removed, an almost linear increase with flow rate is observed.

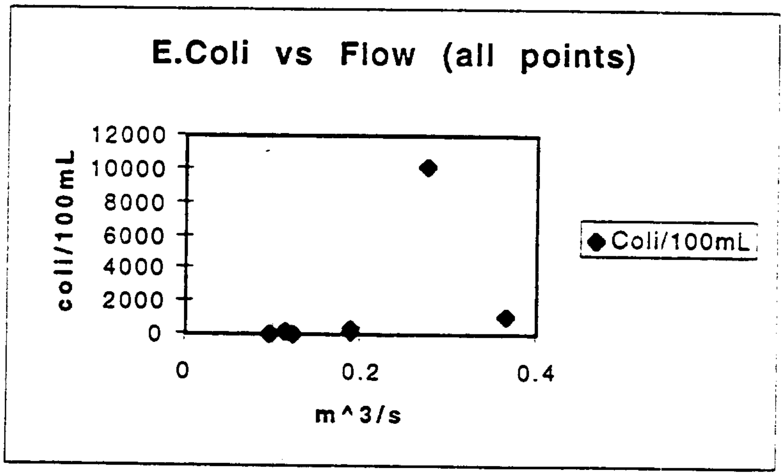

Figure 4. E.Coli count vs Creek Flow Rate (m^3/s)

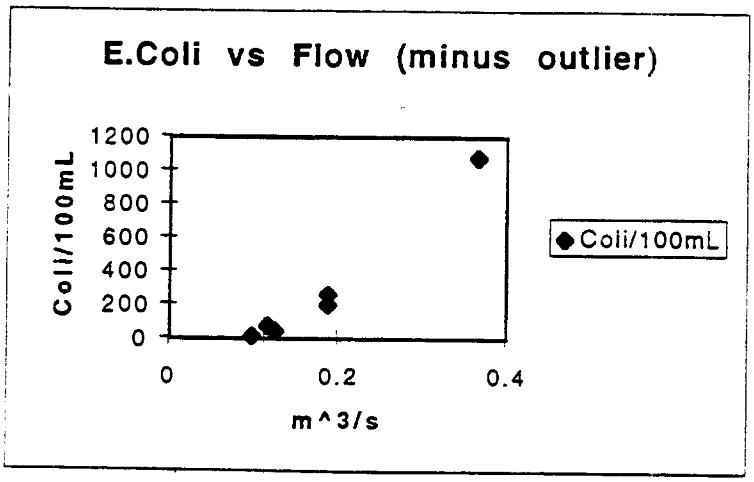

Figure 5. E.Coli count vs Creek Flow Rate (m^3/s) (without outlier)

Figure 6 plots BOD versus the E. Coli count. There is a slight increase in BOD with increasing E. Coli, which suggests that runoff of animal waste or, perhaps, leaking sewer lines may be partially responsible for increased BOD during wet weather. The sanitary sewer system in the area makes much use of the creek valleys as corridors for sewer pipes, and these sewer lines are known to have problems with infiltration during wet weather. Thus there is also potential for "exfiltration" from the overloaded pipes at man holes and at breaks near the top of the sewer lines that do not leak unless the line is nearly full.

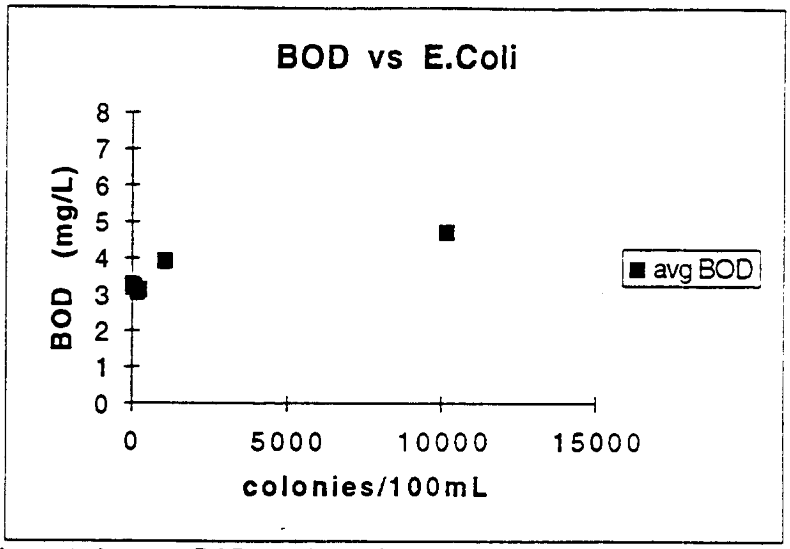

Figure 6. Average BOD (mg/L) vs E.Coli readings taken at the ABC sites

Continuous Monitoring by Electronic Sonde

During most of December, 1997 and the first week of January, 1998, for a period of 35 days, the Crum Creek at site B was monitored continuously using an electronic sonde which recorded data every 15 minutes around the clock.

The reason for deploying the sonde was to catch transient variations in the water quality parameters caused by storm runoff events. Figure 7 shows the daily rainfall totals at the airport for the month of December, 1997. During the rainfall events of December 23, December 25, and December 30, the conductivity exhibited a very interesting transient behavior, first spiking upwards for about one hour, then plunging downwards for the next hour to far below the original value. Figure 8 shows a close-up of the specific conductivity and turbidity on December 23. The specific conductivity is about 580 µS/cm before the runoff reaches the stream, then it rises to 765 µS/cm during the first hour of runoff followed by a drop to 310 µS/cm. The specific conductivity then returns rapidly to 450 µS/cm and begins to decay exponentially until the next rainfall event on December 25, which causes another, less dramatic transient swing.

Abrupt increases in turbidity correspond exactly with the conductivity transients. Close examination of the turbidity data reveals that the turbidity begins increasing at the same time that the conductivity transient begins its upward swing. However, the peak turbidity readings occur when the conductivity reaches the low point of the transient. These results suggest the occurrence of a "two flush" phenomenon in the runoff. The first flush contains high dissolved solids which cause the conductivity to increase. The second flush contains high suspended solids which cause the turbidity to peak and the conductivity to dip.

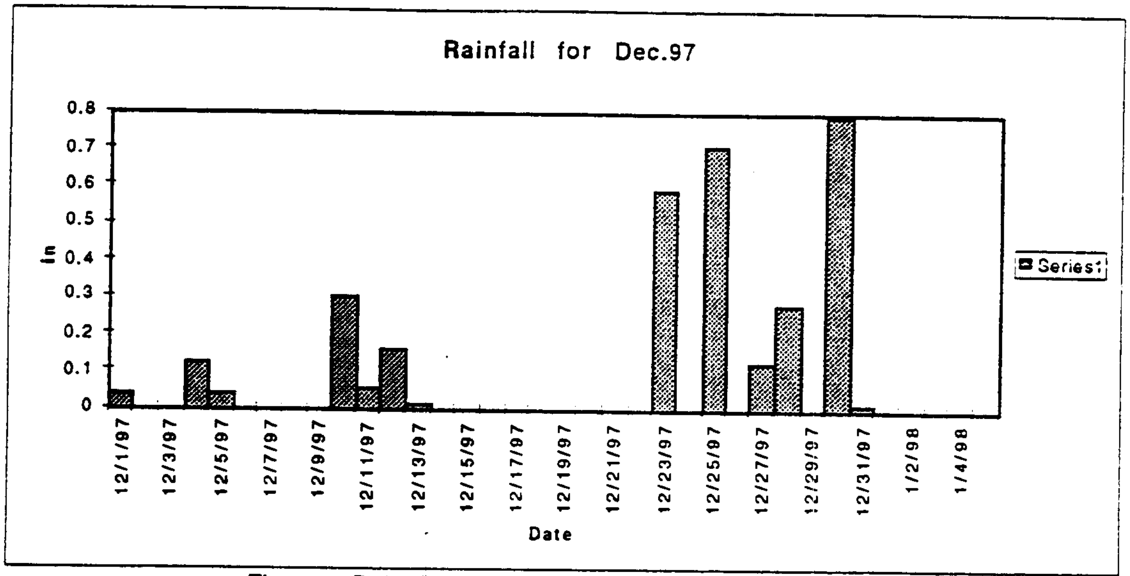

Figure 7. Daily Rainfall Totals in cm. for December, 1997

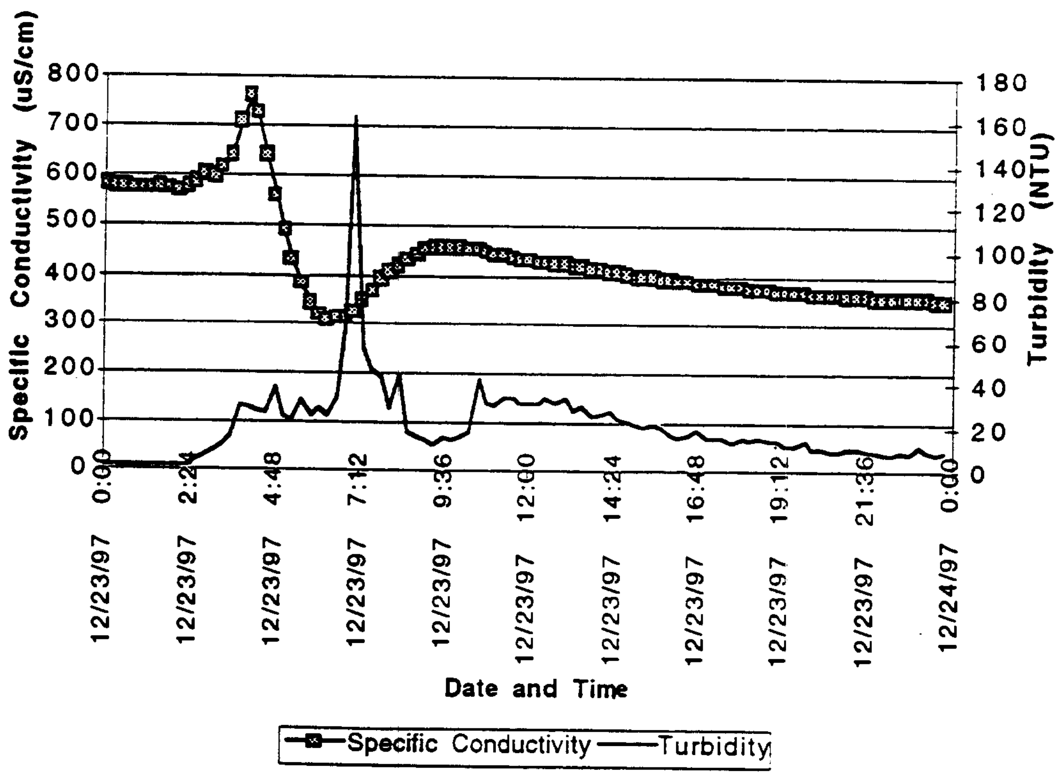

Figure 8. Conductivity and Turbidity Transients for the December 23 Rainfall

The dissolved oxygen data taken with the sonde at site B are displayed in Figure 9. These results show two interesting features, the diurnal cycling of DO, and the effects of rainfall on oxygen concentration in the creek. The diurnal cycling, driving the DO concentration into the supersaturated zone, is probably caused by aquatic plant life and algae upstream from site B, since the peaks occur late in the afternoon or after dark. It is interesting to note that the DO concentration peaks and dips occur at earlier times as the month goes by, suggesting an effect of shorter daylight periods as the winter solstice approaches. The concentration hits its low point between 7:30 and 8:30 AM in the early part of the month and as early as 4 AM, later in the month.

The concentration peaks between 7 and 10 PM in early December, and later in the month, between 3 and 6 PM.

The most obvious effect of rain on oxygen levels is that during periods of heavy rain the cyclical pattern of the DO and deficit is interrupted. As seen in Figure 9, the diurnal cycles are interrupted during rainy days, particularly those with rainfall over half an inch. On 12/13, 12/15, and especially 12/30, the concentration flattened out for several hours.

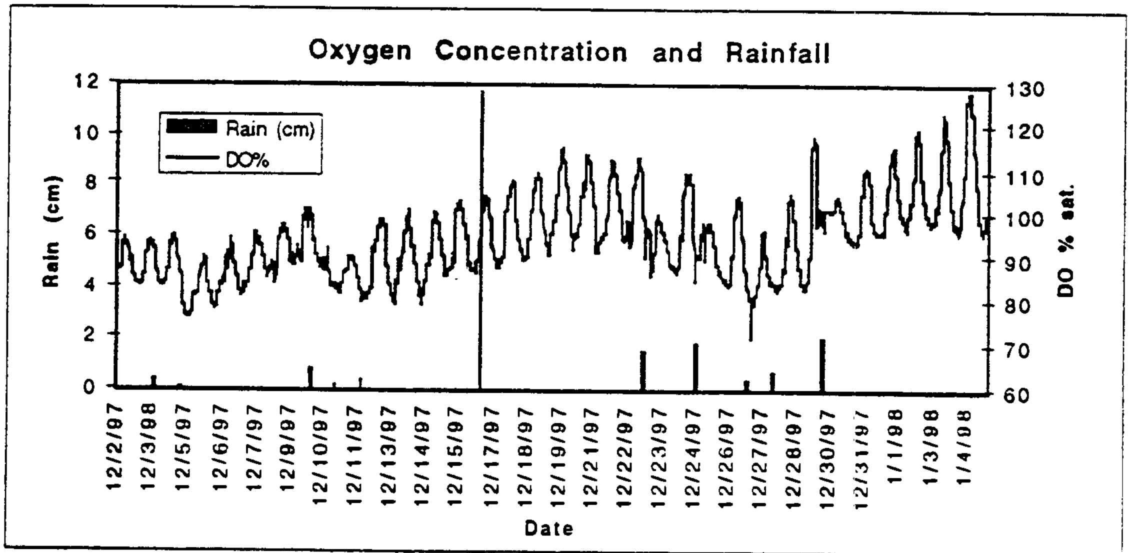

Figure 9. Oxygen Concentration and Rainfall for 12/2/97 to 1/5/98

CONCLUSION

The apparent effect of pools on oxygen deficit in the Crum Creek may be due to several factors. It is clear that in the pools the water is deep and moving slowly enough to allow for the BOD to be exerted, and the rate of oxygen consumption outweighs the rate of reaeration. Then in the riffles, the reaeration rate outweighs the rate of consumption causing the deficit to decrease. Although the BOD in the water column was fairly consistent throughout the sites, sediment oxygen demand may contribute to increased deficit in pools. The creek bottom in pools along the reach examined in the creek walk is nearly always softer, muddier, and covered with more organic material than the shallow, rocky bottom of riffles.

Some indications of the sources of the water column BOD are revealed by this study. Our results suggest that human or animal waste and landfill leachate are partial contributors to the increase in BOD during wet weather. The runoff is probably carrying significant BOD from nearby mall parking lots and Interstate 476, organic materials on the creek banks, and from lawns in neighborhoods through which the creek runs.

While positive and excessive E.Coli counts indicate the presence of animal or human waste in the creek, it is not possible to determine exactly the source of these bacteria from the tests we conducted. There are many Canadian geese living year-round in Smedley park, and their waste may be carried in the runoff from the park during a rain. The possibility that sanitary sewer lines are leaking during wet weather will be investigated further. This type of leak is a common occurrence in other creeks in the area, especially in Little Crum Creeks, which drains most of Swarthmore Borough east of Crum Creek.

ACKNOWLEDGMENTS

The authors would like to acknowledge financial support from Swarthmore College's Howard Hughes Medical Institute grant for undergraduate research and high school outreach. Support was also received from the Swarthmore College Faculty Research Fund.

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QUESTIONS AND ANSWERS FOR SHORT TERM FLOW MONITORING PROGRAMS

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Abstract
Improvements in flow meter technology have continued to increase the accuracy of depth, velocity, total flow and surcharge level measurements in sanitary and combined sewer systems. Short-term flow monitoring programs, often conducted in conjunction with I/I, SSES, and CSO studies, are normally faced with the following three questions:

- When is the ideal time to install short-term monitors?
- How long after installation can adequate dry/wet weather data be gathered?
- What data is needed?

These questions and the response to each can have significant impact on the cost and effectiveness of short-term flow monitoring programs. Based on the flow meter interval (distance between short-term monitors) and the duration of the program, the cost of flow monitoring can approach or exceed the cost of physical inspection activities such as smoke testing and manhole inspection.

Short-term flow monitoring data is often utilized for prioritizing basins for I/I source detection activities, balancing flow monitoring data with quantified source data, and inputs for various hydraulic models. Storms which occur during a short-term monitoring program can normally be categorized as follows:

- System response without surcharge.
- System response with surcharge but no overflows (containment).
- System response with surcharge and overflows (non-containment).

The first category of storm (normally greater than 0.15 inches per hour) can provide data on both wet weather peak flow and volume. The second category can provide data on volume but limited useable peak flow data. The third category normally cannot provide useful data on either. Flow monitoring programs should be established (wherever possible) to maximize the likelihood of monitoring as many of the previous conditions as possible within the shortest possible time period.

Keywords – Flow Monitoring, Rainfall, I/I, SSES

Introduction

The implementation of cost-effective successful short-term flow monitoring programs is an integral part of most urban wet weather pollution reduction planning level studies. These short-term flow monitoring programs are a key component of planning level studies for urban wet weather projects for both combined and separate sanitary sewer systems.

Implementation of cost-effective, successful, short-term flow monitoring programs requires an analysis of three key questions:

- When is the ideal time to install monitors?
- How long is required to gather adequate data?
- What data is needed?

The answers to these general questions will vary from region to region and project to project.

Short Term Flow Monitoring Questions - When, How Long, and What Data?

Improvements in flow meter technology have continued to increase the accuracy of depth, velocity, total flow and surcharge level measurements in combined and sanitary sewer systems. Short-term flow monitoring programs, often conducted in conjunction with I/I, SSES and CSO studies, are normally faced with the following questions:

- When is the ideal time to install short-term monitors?
- How soon after installation can adequate dry/wet weather data be gathered?
- What specific data is normally required?

These questions and the response to each can have significant impact on the cost and sucess of short-term flow monitoring programs. Based on the flow meter interval (distance between short-term monitors) and the duration of the program, the cost of flow monitoring can approach or exceed the cost of the balance of the planning level study such as physical inspection activities like smoke testing and manhole inspection.

<u>Short Term Flow Monitoring Answers</u> - Determining Collection System Response to Storm Events

Answers to the key questions are the first step in implementing a cost-effective and successful short-term flow monitoring program. Although sometimes these answers can be generalized by climatic region, there are often project-specific issues that can influence the final short-term flow monitoring program design.

<u>Timing of Initiation of Short term Monitoring</u> – By definition, short-term monitoring programs are designed to gather necessary data in a relatively short period of time. This process therefore involves compromises that result in the collection of less data than "long-term" monitoring programs that cover more than one climatic season.

The challenge in short-term monitoring programs is often to select the best starting date for the flow monitoring. In most cases, the sanitary or combined sewer system is being studied because it cannot convey flow after intense storm events without surcharging and overflows. As shown in Figure 1 and Figure 2 the response of the sewer system to storm events is also influenced by:

- Antecedent soil moisture conditions
- Ground water levels
- Frozen ground conditions.

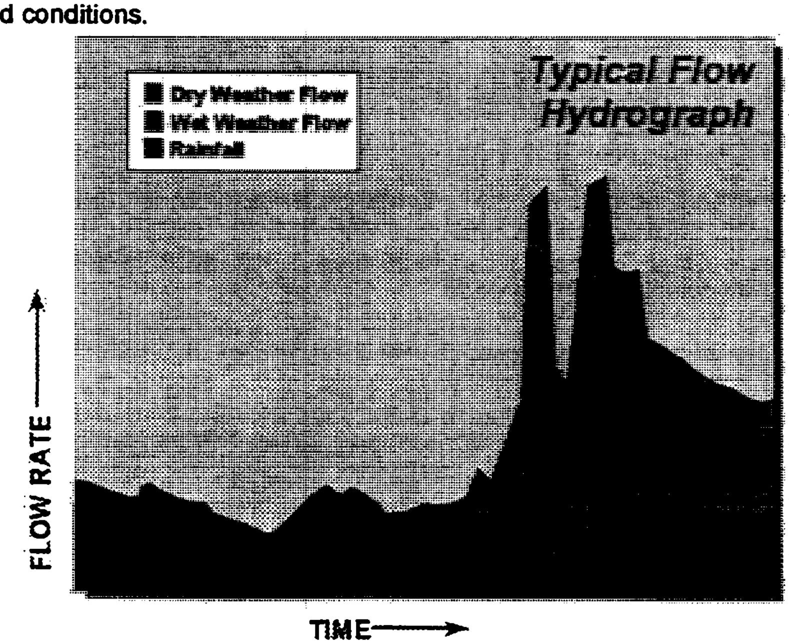

Figure 1

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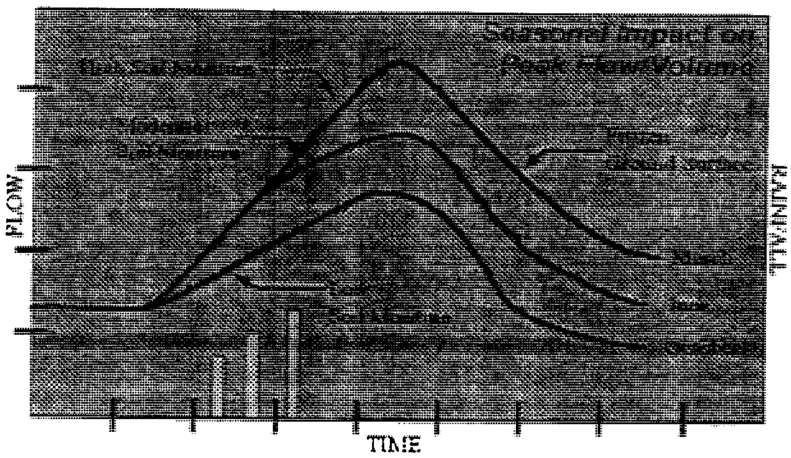

Figure 2

Timing the initiation of a short-term monitoring program is a function of both historical climatic conditions and current year conditions. Timing the programs to start a few weeks before and end a few weeks after seasonal storms provides an opportunity to collect "dry weather" data during the short-term flow monitoring program with a high likelihood of collected data not being influenced by storm events.

Pre-Selection of short-term flow meter locations well in advance of the metering program allows for guide mobilization and installation at the optimal time. The hydraulic characteristics of individual manholes for flow meter installation and operation cannot be properly evaluated without full descent inspection. Completing these flow monitoring manhole inspections well before initiation of the monitoring program prevents the last-minute moving of flow monitors to more suitable locations. Key criteria which normally influence the selection of meter sites include access to manhole, system geometry, localized hydraulics of individual manhole incoming and outgoing line plus bench/trough, close proximity of lift stations, and close proximity of interceptor sewers (especially where collector lines connect to interceptors below the normal flow line in the interceptor).

<u>Short Term Flow Monitoring Program Duration</u>

The ideal short-term flow monitoring program for a sanitary sewer system would be the shortest period in which the following wastewater flow components can be analyzed:

- Base flow (water consumption plus permanent infiltration)
- Peak infiltration (base flow plus peak groundwater induced infiltration)
- Peak inflow (rainfall induced infiltration and/or inflow)

The ideal short-term flow monitoring program for a combined sewer system would be the shortest period in which the following wastewater and urban runoff flow components can be analyzed:

- Base flow (water consumption plus permanent infiltration)
- Peak infiltration (base flow plus peak groundwater induced infiltration)
- Wet weather flow (base flow plus peak groundwater infiltration plus urban stormwater runoff)

Almost every separate sanitary sewer system will experience some level of surcharging after intense storm events, such as a 1-year recurrence interval storm. Analysis of intense storm events requires a reliable methodology for predicting how a wastewater collection system will operate under extreme conditions that cannot be monitored because of system surcharge and sometimes overflows. Any such methodologies are dependent on empirical data analysis and have built-in uncertainties because of the need to project peak wet weather flow and volume up to design storm conditions.

The best mechanism to increase the reliability of any empirical projection technique is to have more data points to correlate. Flow monitoring programs of thirty days or less rarely provide enough data points to produce a reliable correlation. Flow monitoring programs of 90 to 120 days normally do produce 6 to 8 discrete storm events, which typically results in a reliable correlation. Flow monitoring programs between 30 days and 90 days are subject to the uncertainty of local climatic conditions.

The peak flow and volume projection uncertainty requires more research and discussion in relation to SSO regulations. The need to narrow this sometimes large range of uncertainty seems to have been overshadowed by the debate over the relative accuracy of flow meter technology among the major flow meter manufacturers. Calibration of meter sites under high water conditions are critical to establishing peak inflow under design storm conditions. Experience has shown that the hydraulic elements curve (and resulting Manning's equation) is most likely to deviate from actual site hydraulic conditions between 75 percent of full pipe depth and full pipe flow. Adequate on-site calibration of sites after storm events (when flows above 75 percent occur) are necessary to collect this data. It cannot normally be acquired during routine servicing of flow meters.

In some cases, plugging or partial plugging of sewer lines upstream of a meter site followed by quick release of the plug may be necessary to induce high enough flows to do these on-site calibrations. Caution must be exercised, however, to ensure that the sewers downstream of a monitoring site are not subject to hydraulic restrictions that would impact the hydraulics at the meter site. Dye dilution measurements are normally not reliable with a rapidly varying flow rate past a meter site, and are limited by the difficulty in mobilizing quickly and efficiently after a storm event.

The ability of current meter technology to measure "average" flow profile velocity is only one step in the process of predicting sewer system behavior under intense storm events. The other components of SSO events are the volume and duration of the overflow. The relationship between storm recurrence interval and duration and peak wet weather flow volume and duration also relies on empirical data. This relationship is more difficult to quantify than the rainfall and peak flow relationship. The sizing and the resulting cost of deep tunnel storage solutions in large urban systems relies on accurate predictions of wet weather flow volume from the design storm event.

<u>What Specific Data is Normally Required?</u>
Separate sanitary sewer systems have, in most cases, been designed not to surcharge under peak flow conditions. However, the combination of growth and infiltration and inflow (I/I) often results in surcharging after intense storm events. In communities subject to basement backups, detailed modeling of hydraulic grade lines may need to be performed if some level of "acceptable surcharge" is going to be allowed under the design storm, peak wet weather flow. This analysis requires elevation data for manhole rim and pipe inverts along with basement elevations for homes without overhead sewers.

Storm recurrence interval (1-year, 5-year, and others) must always be coupled with storm duration (1-hour, 6-hour, and others) in relation to SSO occurrences. The storm duration most likely to cause SSOs in a sanitary sewer system is approximately equal to the time of concentration of the system tributary to the SSO. On the smaller diameter collection system level, this is often a 30-minute duration storm created by a small storm cell over a small geographic area. On a larger scale, this may be a six-hour duration storm caused by a large storm cell over an entire watershed. The characteristics of the individual system will dictate the "critical" storm duration most likely to cause an SSO occurrence.

Key data needs for each flow component can be summarized as follows:

- Base Flow
Base flow data is normally utilized to compare to water consumption data and then for calibration of hydraulic models. Most systems exhibit repetitive dry weather diurnal flow variations. A large number of dry weather days are normally <u>not</u> required to adequately determine base flow diurnal patterns. Normally, one week of complete data that has not been impacted by storm events is adequate. Ideally, this one week period is isolated by at least three weeks from any significant storm events or snow melt conditions.

- Base Flow Plus Peak Infiltration

Base flow plus peak infiltration data is normally used to evaluate the rate of groundwater infiltration into the sewer system by individual basin as well as to calibrate hydraulic models for base flow plus peak infiltration conditions. A large number of days of base flow plus peak infiltration data are normally not required to adequately determine system flows under these conditions. One week of complete data that has not been impacted by storm events is normally adequate. Ideally, this one-week period is isolated by at least three days from any significant storm events. The three-day period normally allows for rainfall-induced infiltration to taper off after the end of the storm event, leaving the system subject to strictly groundwater level-induced infiltration.

- Base Flow Plus Peak Infiltration and Inflow

This data is dependent on the occurrence of intense storm events. The ideal confirmation of high groundwater levels and intense storm events provides system data under "worst case" conditions for system conveyance capacity.

The determination of how many SSO events per year will occur, and the duration of each event needs to account for the impact of antecedent moisture conditions. SSO system solutions designed around design storm events during low soil moisture conditions typically will result in system surcharge and continued SSO events for the design storm after rehabilitation construction.

This same phenomenon can be observed when a second intense storm event occurs shortly after an initial intense event. The response to the second storm is disproportionally higher and more likely to cause an SSO occurrence than the first storm event.

Intense rainfall occurrences vary dramatically from one region to another. For example, the 5-year, 60-minute duration storm for New Orleans is approximately 8.89 cm/hr (3.5 in./hr), while the same storm in Northeastern Illinois is only 4.83 cm/hr (1.9 in./hr), a difference of 84 percent. If it can be assumed that the occurrence of SSOs is related to rainfall intensity and duration, then it could be far more costly to limit overflows in New Orleans to one SSO event per year than in Chicago.

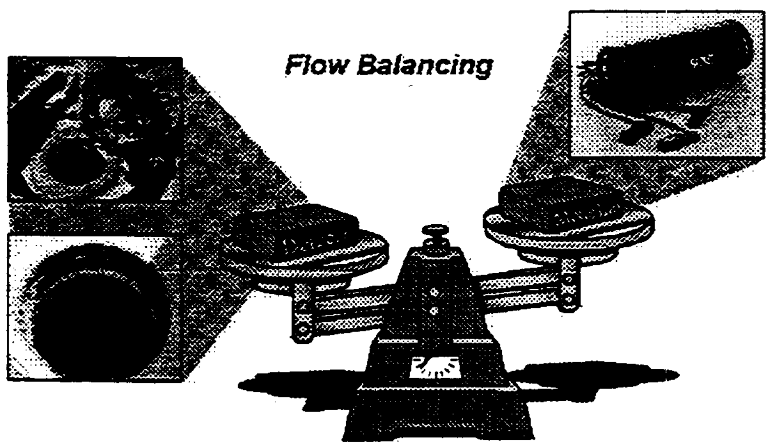

Figure 3

A reliable correlation between rainfall intensity and a stormwater inflow is critical to developing a source data/flow data balance. As shown in Figure 3, this flow balance compares the peak one-year storm inflow (or other appropriate storm reoccurrence interval) to the sum total of all qualified I/I source defects. This reliable correlation is also important in evaluating post-rehabilitation flow monitoring data. As shown in Figure 4, the system response to intense storm event must be compared at the same flow monitoring locations both before and after system rehabilitation to accurately determine the magnitude of wet weather flow reduction as a result of system rehabilitation.

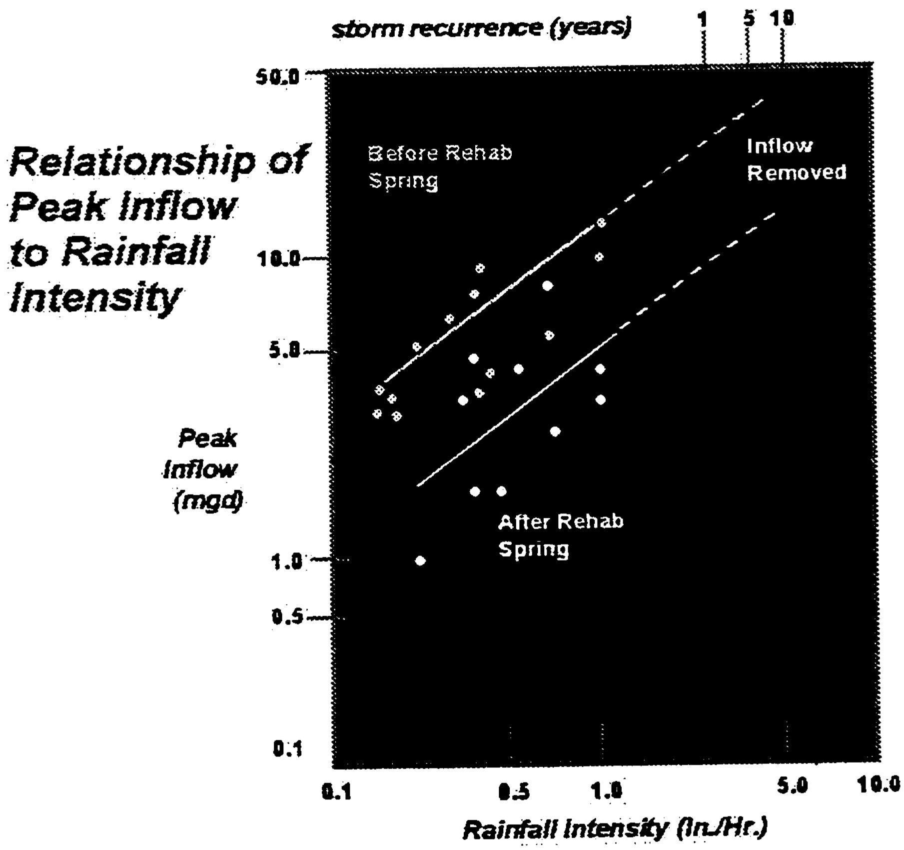

Figure 4

Conclusions

Short-term flow monitoring programs should be designed to focus on the purpose for which the data will be used. The nature of local climatic conditions will influence both the starting date and the duration of the program. Starting dates approximately two weeks prior to initiation of the normal "storm season" are preferable. A minimum of 90 days and preferably 120 days of short-term monitoring are necessary to determine a reliable relationship between rainfall intensity and stormwater inflow.

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Expanding the Coverage of the NPDES Storm Water Program: The Proposed Phase II Rule

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ABSTRACT

On January 9, 1998 EPA published in the Federal Register "Proposed Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges", or commonly referred to as the NPDES Storm Water Phase II proposed rule. EPA requested comments on this proposed rule until April 9, 1998. The proposal designates two classes of facilities for automatic coverage on a nationwide basis under the NPDES program, (1) small municipal separate storm sewer systems located in urbanized areas (about 3,500 municipalities would be included in the program); and (2) construction activities (pollutants include sediments and erosion from these sites) that disturb equal to or greater than one and less than five acres of land (about 110,000 sites per year will be included in the program). Those facilities designated above would need to apply for NPDES storm water permits in 2002. EPA is anticipating that most permittees would be covered under general permits.

EPA is also proposing to conditionally exclude from the NPDES storm water program Phase I facilities that have "no exposure" of industrial activities, such as industrial products, processes, or raw materials, to storm water, thereby reducing application of the program to many industrial activities currently covered by the program that have no industrial storm water discharges.

KEYWORDS

storm water, Phase II, NPDES

FINAL RULE

<u>NOTE</u>: The Phase II rule was proposed on January 9, 1998 and is currently scheduled to be finalized by March 1, 1999. This paper discusses the requirements in the proposed rule. For information on the final NPDES Storm Water Phase II rule after it is published in March 1999, contact EPA's Office of Water (web site http://www.epa.gov/ow).

BACKGROUND

Congress added Section 402(p) to the Clean Water Act in 1987 which requires implementation of a comprehensive approach for addressing storm water discharges. This section requires NPDES permits for storm water discharges associated with industrial activity and municipal separate storm sewer systems (MS4s) serving populations greater than 100,000. EPA issued final regulations for these 'Phase I' sources on November 16, 1990.

Section 402(p)(6) requires EPA, in consultation with States and local officials, to issue regulations for the designation of the remaining unregulated discharges to be regulated to protect water quality based on studies conducted under section 402(p)(6). These studies resulted in a Report to Congress on potential phase II discharges (EPA, 1995), which recommended that the storm water program focus on the 405 "urbanized areas" identified by the Bureau of the Census.

EPA developed the proposal with extensive outreach and stakeholder involvement. Valuable input was received from a cross section of interested stakeholders including members of a subcommittee under the Urban Wet Weather Federal Advisory Committee (Phase II FACA Subcommittee). The Phase II FACA Subcommittee included representatives from municipalities, industrial and commercial sectors, agriculture, environmental and public interest groups, States, Indian Tribes, and EPA. The FACA subcommittee has met thirteen times between September 1995 and April 1997, providing valuable comments and feedback.

EPA also convened a Small Business Advocacy Review Panel to evaluate and minimize the potential impact of the proposed rule on small entities.

The proposed rule was signed by Administrator Browner on December 15, 1997 and published in the Federal Register on January 9, 1998. The comment period was open until April 9, 1998 with a final rule scheduled to be signed by March 1, 1999. The following sections summarize the three main components of the rule: the Phase I no exposure revision, small construction sites, and regulated small MS4s.

PHASE I NO EXPOSURE REVISION

"No exposure" means that all industrial materials or activities are protected by storm resistant sheltering so that they are not exposed to rain, snow, snowmelt, or runoff. Industrial facilities (except for construction) which document that they have "no exposure" to storm water could apply for a conditional exemption from the Phase I storm water requirements. EPA has proposed a two page checklist for no-exposure certification for NPDES Storm Water Permitting in the proposed rule. The owner or operator must submit a written certification to the NPDES permitting authority once every five years.

SMALL CONSTRUCTION

The proposal extends existing Phase I regulations to apply to construction activities including clearing, grading, and excavating activities that result in land disturbance of equal to or greater than one acre and less than five acres. Sites disturbing less than one acre are included if they are part of a larger common plan of development or sale with a planned disturbance of equal to or greater than one and less than five acres. The permitting authority may also designate sites less than one acre based on the potential for contribution to a violation of a water quality standard or for significant contribution of pollutants to waters of the United States. The operator of the construction site would be responsible for applying for the NPDES permit. EPA anticipates that most permittees would be covered under general permits.

The permitting authority may waive the requirement for a notice of intent (NOI) under a general permit for construction sites less than 5 acres. In addition, to minimize redundancy in the construction permit requirements, permitting authorities can incorporate by reference the requirements of qualifying State, Tribal or local erosion and sediment control programs.

The NPDES permitting authority may waive the otherwise applicable requirements for a storm water discharge from construction activities that disturb less than five acres where:

(1) The rainfall erosivity factor ("R" in the Revised Universal Soil Loss Equation) is less than two during the period of construction activity. This is the "low rainfall" waiver provision. The owner/operator must certify that construction activity will take place during the period when the rainfall erosivity factor is less than two;

(2) On a case-by-case basis the annual soil loss for a site will be less than two tons/acre/year. The owner or operator must certify that the annual soil loss for their site will be less than two tons/acre/year through the use of the Revised Universal Soil Loss Equation, assuming the constants of no ground cover and no runoff controls in place; or,

(3) Storm water controls are not needed based on either: (i) Wasteload allocations that are part of "total maximum daily loads" (TMDLs) that address the pollutants of concern. The owner or operator must certify that the construction activity will take place, and storm water discharges will occur, within an area covered by the TMDLs; or, (ii) A comprehensive watershed plan, implemented for the waterbody, that includes the equivalents of TMDLs, and addresses the pollutants of concern. The owner or operator must certify that the construction activity will take place, and storm water discharges will occur, within an area covered by the watershed plan.

Within urbanized areas, construction activities are proposed to be covered by the municipal storm water program, which is discussed in the next section. The waivers discussed above and the ability to incorporate by reference qualifying State, Tribal, or local erosion and sediment control programs also apply to the municipal construction minimum measure.

REGULATED SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEMS

The proposed Phase II rule would apply to owners or operators of small municipal separate storm sewer systems (MS4s) located within an "urbanized area" (defined below). Permitting authorities are required to evaluate for potential designation all small MS4s located outside of urbanized areas with a population of at least 10,000 and a population density of at least 1,000. In addition, permitting authorities may designate small MS4s that contribute substantially to the storm water pollutant loadings of a physically interconnected MS4 that is regulated by the NPDES storm water program or based on significant contributor of pollutants to waters of the U.S.

The municipal component of this proposed rule applies to urbanized areas as determined by the latest Decennial Census by the Bureau of the Census. An urbanized area is generally defined as "a place and the adjacent densely settled surrounding territory that together have a minimum population of 50,000 people." The "densely settled surrounding territory" generally has a population density of at least 1,000 people per square mile and is contiguous with other qualifying territory. There are 405 urbanized areas in the U.S. that cover 2 percent of the total U.S. land area and contain approximately 63 percent of the nation's population (these statistics include Phase I cities).

The owner/operator of the regulated small MS4 must develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP) and protect water quality. The storm water management program must include the six minimum control measures described below and identify BMPs and measurable goals for each minimum control measure. The program can incorporate by reference qualifying local, State or Tribal requirements and there is a requirement to evaluate program compliance, the appropriateness of the identified best management practices, and progress towards achieving the identified measurable goals.

MINIMUM CONTROL MEASURES

The following six minimum control measures must be a part of the storm water management program developed by the regulated small MS4. The permitting authority will issue a menu of regionally appropriate and field-tested BMPs that they believe to be cost-effective. This menu of BMPs can be used by the municipality to select BMPs for the minimum control measures.

(1) *Public education and outreach on storm water impacts*. The municipality must implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of storm water discharges on water bodies and the steps that can be taken to reduce storm water pollution.

(2) *Public involvement/participation*. The municipality must comply with State, Tribal and local public notice requirements. For example, provide opportunities for the public to participate in program development.

(3) *Illicit discharge detection and elimination*. The municipality must develop a sewer system map of major pipes, outfalls and topography; effectively prohibit illicit discharges and implement appropriate enforcement procedures; implement a plan to detect and address illicit discharges; and inform the public of hazards associated with illegal discharges and improper disposal of waste.

(4) *Construction site storm water runoff control*. The municipality must develop, implement, and enforce a program to reduce pollutants in storm water runoff to the MS4 from construction activities of greater than or equal to one acre. The municipality must also use an ordinance that controls erosion and sediment to the maximum extent practicable and control other waste at the construction site that may adversely impact water quality, such as discarded building materials, concrete truck washout, and sanitary waste. The program must also include, at a minimum, requirements for construction site owners or operators to implement appropriate BMPs, provisions for pre-construction review of site management plans,

procedures for receipt and consideration of information submitted by the public, regular inspections during construction, and penalties to ensure compliance.

(5) *Post-construction storm water management in new development and redevelopment.* The municipality must develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects that result in land disturbance of greater than or equal to one acre and that discharge into the MS4. The program must include a plan to implement site-appropriate and cost-effective structural and non-structural BMPs and ensure adequate long-term operation and maintenance of such BMPs. The program must also ensure that controls are in place that would prevent or minimize water quality impacts.

(6) *Pollution prevention/good housekeeping for municipal operations.* The municipality must develop and implement a cost-effective operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations.

PROPOSED DEADLINES

Proposed Rule Becomes Final	3/1/99
Permitting Authority Issues Menu of BMPs for Regulated Small MS4s	3/1/01
Permitting Authority issues General Permits	3/1/02
Regulated Small MS4s submit permit applications	5/31/02
Small Construction submits permit applications	5/31/02
Regulated Small MS4 programs Developed and Implemented	2007

TOOL BOX

EPA is developing a "tool box" to assist States, Tribes, municipalities, and other parties involved in the Phase II program. EPA is committed to having a preliminary working tool box by the time the proposed rule is finalized in March 1999 and a fully operational tool box at the time of the general permit. The tool box will consist of the six main components: fact sheets, guidances, an information clearinghouse, training and outreach efforts, technical research, and support for demonstration projects.

SUMMARY OF MAJOR COMMENTS RECEIVED

EPA received 500 comments from States, Tribes, municipalities, Federal agencies, environmental groups, contractors, industries, and associations representing all stakeholders.

No exposure provision
Many commenters expressed strong support for the no exposure provision. Some commenters wanted the change implemented quickly rather than waiting for the phase 2 rule. There were also numerous comments and requests for clarification on specifics of the no exposure check list.

Small construction site requirements
Municipalities and contractors submitted extensive comments on the requirements for small construction sites. Many of these commenters stated that EPA does not have data that demonstrates a need to regulate small construction sites. EPA also received comments asking for additional waivers and complaints about the difficulties involved in implementing the proposed waivers.

Permitting approaches
Most of the commenting States and some municipalities supported the use of State alternatives to the NPDES approach. The environmental groups along with a few States and municipalities supported requiring an NPDES approach. Many commenters expressed strong support for general permits and for not requiring NOIs for small construction sites. Many commenters wanted the rule to be clearer about implementation issues such as allowing Phase 2 municipalities to work together in developing their programs and submitting their NOIs.

Six minimum measures
Municipalities and DOTs commented that EPA or the State should be responsible for public education. Several municipalities and States asked for clarification on the illicit discharge requirements. Municipalities and contractors stated that the new development/redevelopment measure is impossible to achieve.

Municipal coverage
A number of States and municipalities asked for revisions to Appendix 6 or clarifications on urbanized areas and incorporated places. They also had numerous comments about the designation criteria, stating that it is too burdensome to apply and EPA has no justification for designating municipalities based on population. Several of these commenters also stated that the rule pushes development outside of urbanized areas, thereby encouraging urban sprawl. Commenters made various suggestions for expanding municipal waivers to exclude more small municipalities.

Municipal storm water management program
Many municipalities commented that municipal regulation of construction sites is redundant; the rule violates the 10th amendment; and the rule interferes with local land use planning. They also said that there should be no effluent limits or monitoring and the rule should not mention TMDLs.

Costs and benefits
Many municipalities and contractors stated that EPA underestimated the rule costs and overestimated the benefits while environmental groups stated that EPA overestimated the costs and underestimated the benefits. Municipalities also stated that the rule is an unfunded mandate. Several States and municipalities mentioned that they could not implement the rule without additional funding.

Overall
Municipalities stated that EPA should consider agricultural sources when regulating storm water and that EPA needs to better evaluate Phase 1 before issuing Phase 2. They also commented that EPA should only regulate places with known water quality problems. Municipalities and several municipal associations stated that EPA should not mention flow while environmental groups and some Tribes stated that flow must be addressed.

Differences among MS4s
Several groups commented on specific issues that they believe should allow them to have different requirements or more flexibility in implementation. These include State DOTs, military facilities, and cities with CSOs.

ADDITIONAL INFORMATION

This rule fulfills a major part of the commitment made by the President's Clean Water Action Plan announced on February 19, 1998 (information on this is at http://www.epa.gov/cleanwater). Copies of the proposed rule can be obtained from the January 9, 1998 Federal Register, EPA's web site at http://www.epa.gov/OWM/sw2.htm or limited paper copies are available by calling the Water Resource Center at (202) 260-7786. If you have questions on the proposed rule, please email them to sw2@epamail.epa.gov or call (202) 260-5816.

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EFFICIENT/EFFECTIVE DATA COLLECTION PROGRAM YIELDS A RELIABLE HYDRAULIC MODEL

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ABSTRACT

Hydraulic modeling of wastewater utilities has become a critical component in the overall assessment of the operational characteristics of sewerage collection and conveyance systems. Modeling allows for identification of conduit capacity limitations and locations within the systems that may be more susceptible to overflows. While the findings of modeling have become more critical, the importance of providing defendable conclusions is sometimes overlooked. Models are routinely developed from outdated, or unreliable data, and although the modeling results greatly affect the decisions to perform costly improvements, the need to build a precise model sometimes becomes a secondary issue. In many cases, the detailed attribution, which is necessary to develop a reliable model, exceeds the cost of the modeling effort itself and therefore the necessary activities are not performed. The question then becomes, how much of the existing data should be checked, and when does it become imperative that new data be collected? The importance of constructing a model that emulates real life hydraulics should be intuitive, but in some instances the lack of operational data has forced modelers to establish conservative initial assumptions, which in fact sway the results before any actual modeling is undertaken. While the impacts of improving system hydraulics has a relatively high price tag, the cost to assemble a reliable model is rarely factored into a matrix that could justify its worth.

This paper discusses how a hydraulic model can be developed that will ensure the level of accuracy that should be required as part of any hydraulic evaluation of wastewater piping systems. When properly assembled, the achieved model will not only be reliable, but also defendable if required.

KEYWORDS

Modeling, Inflow, Infiltration, Flow Monitoring, GPS

INTRODUCTION

How many times have you heard the saying "Garbage In, Garbage Out"? Never has it been more true than when one looks at hydraulic modeling. Routinely during some phase of a hydraulic modeling endeavor the validity of the data being input has been questioned. Much of the concern evolves when systematic hydraulic inadequacies are displayed onto the computer screen during the modeling process. The problems identified are generally caused by relatively flat or negative pipe slopes for gravity systems, or insufficient pipe size for both pressure and gravity systems. While the model may have been developed from some archaic scroll dating back to the 1940s, or 'as-built' information from several projects with different vertical datums, the actual piping size, slope and configurations are rarely field verified.

Having spent a significant portion of their respective careers completing Sewer System Evaluation Surveys, the authors recognize the importance of having accurate data to help establish the specific hydraulic characteristics of wastewater collection/conveyance systems. Groundwater infiltration and storm water inflow (I/I) volumes are easy to attain, but determining the impact of the additional flows is nearly impossible if the location and elevation of the piping system have not been established. In far too many cases the mapping used to select the flow monitoring sites was outdated and did not reflect the actual piping configuration. Without conducting inventory/condition surveys of the structures it is nearly impossible to determine the limits of a drainage basin, or the flow direction of the piping system. The most essential part of building a reliable model is the proper establishment of the existing system hydraulic parameters. These parameters include location of the piping systems; appurtenances, pipe size, material, and depth; and miscellaneous pumping conditions including wet well size, pump capacity, and cycle times.

DISCUSSION

There are numerous means for accurately establishing the actual location of the piping systems. Conventional surveying methods can be utilized, but the fastest growing method involves the use of global positioning systems (GPS), or a combination of both conventional means and GPS. It has been established that GPS surveys can be completed up to 50 percent faster than traditional methods; however, many limitations exist that may make this method cost prohibitive. Limited satellite coverage and working under dense vegetation is probably the greatest restriction for the GPS method, but fortunately there are several ways to utilize the equipment effectively for most circumstances. Before GPS, traversing between a known point to the point of interest was required. Depending on the distance between the two points a survey crew could spend the better part of a day just locating one point. With GPS, this point can be established in most cases in less than an hour and in some cases in as short of time frame as five seconds. Because of the various modes of operation for GPS surveys—static, real time kinematic, and kinematic—various levels of precision can be attained and are primarily dependent upon the time of occupation. With location accuracies ranging from sub-meter to centimeter the proper mode of operation is usually established by the specific requirements of each contract. As with most commodities, as the precision increases the cost for the additional accuracy also increases. An established standard of 3-5 centimeter accuracy, for both vertical and horizontal components, has been utilized on many utility inventory projects, but the cost for this level of accuracy can in some cases exceed the cost of the modeling effort, depending on the size of the system being modeled. On other projects, a cost effective approach has been to establish a known point within the system being modeled with a high-end accuracy GPS survey and to use a faster, less accurate GPS mode to establish the horizontal locations. After the location of the structures has been identified a traditional leveling survey is completed to establish the vertical component. The approach is fairly simple and can be conducted efficiently for most projects. Several hundred structures can easily be horizontally located within a day and a sub-meter level of accuracy is adequate for most modeling efforts. It is important to note that establishment of the vertical element requires a much higher level of accuracy because differences of several centimeters will in some cases drastically affect the modeling results.

The faster, less accurate GPS surveys utilize single frequency receivers and are generally implemented on utility mapping projects. The photograph below (Figure 1) shows a two-man crew with single-frequency GPS receivers mounted on bicycles. This crew can easily locate 500 utility elements in a day, including limited attribution.

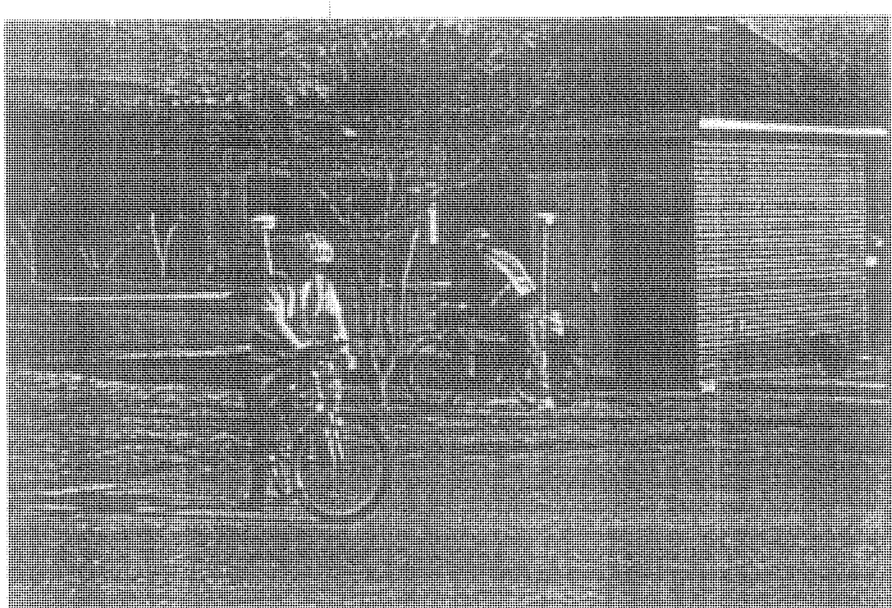

Figure 1 Two-man crew with single-frequency GPS receivers

Upon completion of the GPS activities, a map is produced that identifies the location and unique identifier of each utility element. This map is created electronically and can be overlaid onto any digital mapping file. Electronic mapping can be attained from a variety of sources, including United States Geological Survey, (USGS), or ADC, Inc., but the important aspect of the overlay is that the final attribution crew can easily determine where they are on the map and that the structures being inspected correspond with the unique numbering system established during the initial GPS survey. Final attribution establishes piping size, depth, material characteristics and hydraulic, or structural, deficiencies. In most cases, the final attribution requires confined space entry, but trying to accurately determine pipe size and material from 20 feet above the piping system is nearly impossible. To help build the model efficiently, it is recommended that a project database be created that stores all the attribution data. It is also recommended that the database be accessible from the hydraulic modeling software. For most SSES projects, the goal is to bring back accurate data from the field, and to store it in a easily retrievable format. Numerous off-the-shelf software systems have been developed for this exact purpose and can be interfaced with most modeling systems. The image below (Figure 2) depicts a computer screen from the Hansen Infrastructure Management System (IMS) Sewer Module, Version 7, and highlights the various attribute information that is stored from an internal pipeline inspection. When compiled with the manhole inspection data, this information can be electronically implemented to create the hydraulic model.

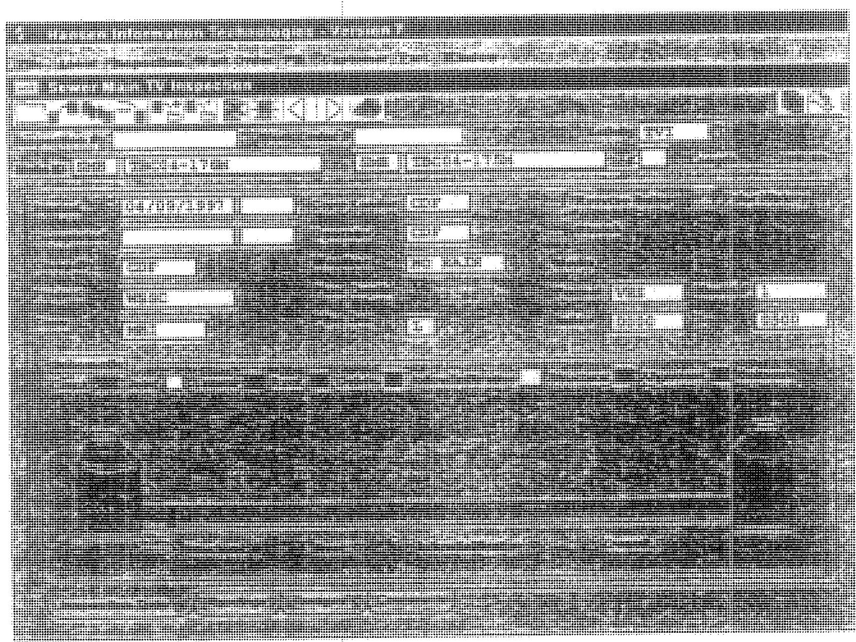

Figure 2 Computer screen from the Hansen Infrastructure Management System, Version 7

With the map created and the final attribution completed, the model can then be developed utilizing most standard CAD files, from a point and click environment. The modeler can select the limits of the systems being evaluated and begin inputting flow data. In most cases, accurate data exists for establishment of average hourly dry weather, and peak dry weather flows. Dry weather flow patterns can be established by utilizing water usage records and by introducing flows into the system on a pipe section-by-pipe section basis that correlates building addresses with piping location. These results, when compared to metered flow rates within the system, should be comparable and may be used to calibrate the model. It is important to establish which facilities within the study area are utilizing metered water and are not returning it to the wastewater system, and potentially which facilities are utilizing well water and are discharging into the conveyance system. If an accurate portrayal of the hydraulics cannot be established for dry weather flows it will be impossible to model the impacts of any wet weather event.

By utilizing open channel flow meters and comparing water usage records to dry weather flow rates, a quick analysis can be completed to identify the potentiai of excessive groundwater infiltration. By isolating flows during non-peak water usage hours (1:00 a.m.-5:00 a.m.), it is fairly easy to identify which piping systems experience significant infiltration. Because the open channel flow meters are usually installed in a mini-basin-by-mini-basin application, and each mini-basin generally has in excess of 10,000 linear feet of gravity piping, additional evaluation is required to quantify the volume of infiltration entering each piping run. Night flow isolations are performed using pre-calibrated weirs or other means to determine the infiltration rates for each piping run. The isolations can be completed from manhole to manhole, or can be completed for several piping sections. The infiltration rates established from the night flow isolations are then added to the flows determined by water usage records and the total flow measured by the open channel flow meter should be comparable. It is important to realize that the actual volume of water entering the collection piping from system users may vary from that being metered at the curb and that an allowance for this occurrence must be made. If accurate groundwater infiltration rates are established, the required variance will establish itself. Groundwater elevation establishment is also very important and in some cases has led to the development of individual models for both high and low groundwater conditions.

A reliable model has now been developed and capacity limitations for average hourly dry weather and peak dry weather flows can be determined. Locations where SSOs are more likely to occur can accurately be depicted and the cost of remediation generated. With the model for dry weather conditions established the impact of inclement weather on the collection/conveyance system can now be evaluated. The overall storm water inflow quantification of an individual rainfall event is simple to measure, but the effect of different magnitudes of rainfall of varying durations is much harder to predict. To property establish these effects it is imperative that the modeler have at least three metered events to use for model calibration. For this reason collection of accurate rainfall data becomes a very important aspect of the calibration procedure. It is very important that incremental rainfall over the mini-basin being monitored is accurately measured and that flow spikes caused by direct inflow are separated from increased volumes associated with rainfall induced infiltration (RII). If the inflow volumes warrant identification of the source(s) a smoke/dye testing program is usually undertaken. Without these activities the modeler has relatively no idea where in the piping system the additional flows are being introduced, and therefore what the impact of removal will have on individual potential overflow locations. Upon completion of the smoke and dye testing activities the model can be rerun without the established direct inflow volumes and the impact of only RII can be measured. If there was an abundance of funding for system rehabilitation this would not be a great issue, but because the most expensive element of reducing wet weather flows pertains to elimination of RII it is one of the most important features to establish. Utility owners and operators want to know how much it will cost to eliminate the overflows and the total cost savings of performing the remediation.

CONCLUSION

In summary, the following elements are key to successfully completing a hydraulic modeling project:

- Accurately map the piping system- GPS is an efficient tool
- Perform the necessary attribution - Properly retrieve the data
- Conduct open channel flow metering - Ensure proper calibration/operation
- Establish a dynamic dry weather model - Utilize infiltration data
- Determine impacts of wet weather events - Complete smoke/dye testing

With the establishment of an accurate model built on real data, a powerful tool has been created—a tool that will allow for proper recommendations to be made for improving system hydraulics and thus minimizing the negative environmental affects caused by SSOs. The model will also serve as a great tool to gauge the impact of future development and to identify potential future operational needs. If a project involving hydraulic modeling is to be successful the basic informational needs to build a reliable model must be understood and accepted by everyone involved in the project. If the proper steps are not completed, and the operational data not validated, the modeling results should be accompanied by a disclaimer that identifies the data sources utilized, the assumptions made and the potential limitations of the model, because everyone should recognize "Garbage In" does equal "Garbage Out" when it comes to modeling.

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OPTIMIZATION OF OFF-LINE STORAGE TANK OPERATION USING REAL TIME CONTROL MODELING

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ABSTRACT

Hydraulic modeling is becoming an integral process of sewer planning studies. Dynamic models are being used to simulate flows and depths in complicated sanitary sewer systems and analyze the operation of storage facilities controlled by real time control (RTC) systems. The modeling process involves calibration against dry weather and storm flows ensuring processes such as storage tank filling and emptying are modeled correctly. Applications for the calibrated models include predicting spill locations, improving tank storage operation and pre-design of major capital projects.

KEYWORDS

Sewer, hydraulic, dynamic modeling, operations, force mains, pump stations, real time control, maintenance, in-system storage, peak flows, optimization

INTRODUCTION

In 1989, two off-line sewage storage tanks were constructed in the pumping station no. 50 (PS 50) basin of the Baton Rouge sanitary sewerage system which was prone to frequent SSO activation. Since the tanks were commissioned there has been a significant reduction in SSO spillage, however the tanks have not been as effective as expected in eradicating SSO's.

A component of the Baton Rouge SSO corrective action plan has been to develop dynamic hydraulic models of the sewerage system calibrated against recorded flow and rainfall. Model construction included the development of Real Time Control (RTC) code to simulate the operation and performance of two major off-line storage facilities during the recorded storm events.

Once the model was calibrated, a series of historical storms were simulated on the model to analyse the current system operation. From this analysis a number of operational modifications and system augmentations were proposed and simulated on the model to optimize the use of the tanks and reduce the frequency of SSO spillage.

BATON ROUGE SEWER SYSTEM

The Baton Rouge sewerage collection system consists of over 36,000 manholes, approximately 2516 km (1564 miles) of gravity sewer, over 400 pumping stations, two major pressurized collection systems containing approximately 307 km (191 miles) of forced mains, two off-line storage tanks and three major waste water treatment facilities which discharge to the Mississippi.

The PS 50 basin has a contributing area of over 2000 ha (5000 acres) and is located in the north east portion of the South Consolidated Sewer District (SCSD). Pumped flow from PS 50 is directed into a gravity trunk main located due south via a 480m (1580 ft) long 500mm dia. (20 inch) force main. Average dry weather flows through PS 50 are 0.20 m^3/s (4.56 MGD) with peak wet weather pumping capacity of

0.41 m^3/s (9.4 MGD). Figure 1 illustrates the major components of the PS 50 sewer system included in the model.

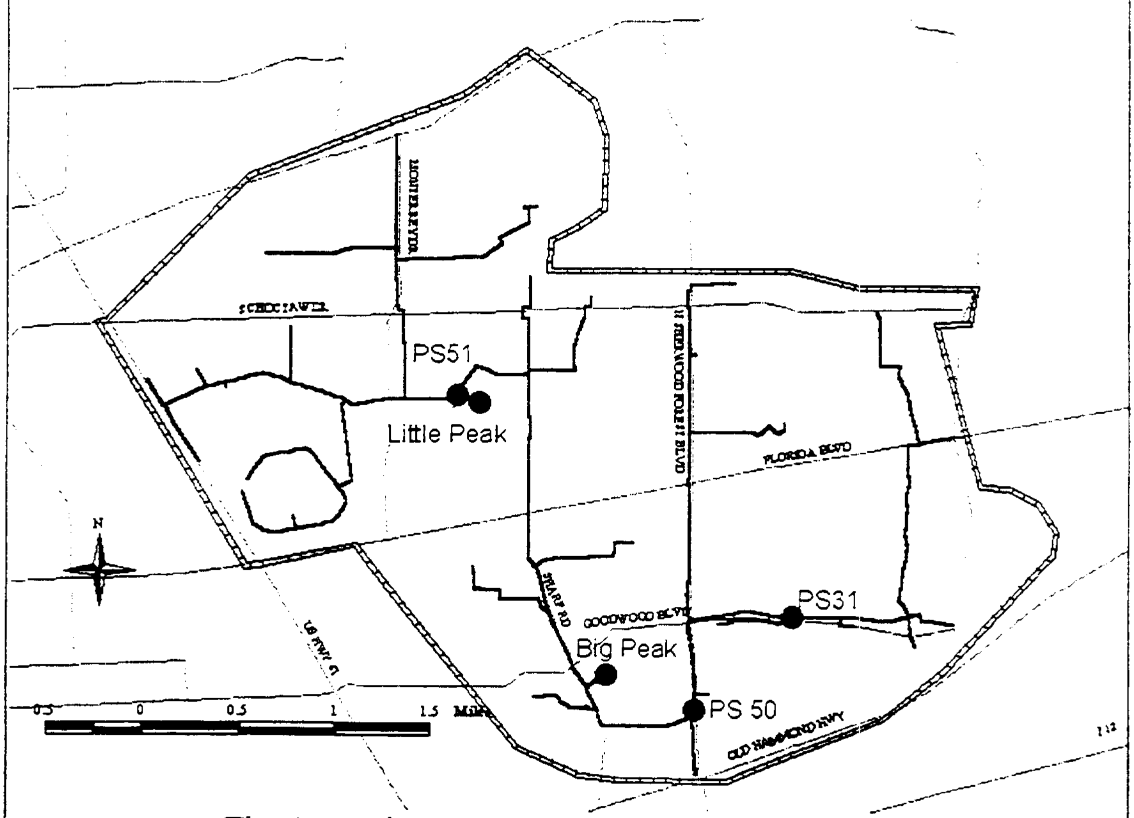

Fig. 1 Major Sewer Components in PS 50 Basin

SEWER MODELING USING HYDROWORKS

The sewer model used for the hydraulic analysis of the Baton Rouge system is HydroWorks™ (Version 3.3). The package simulates time-varying flows and depths generated from dry weather and wet weather flow inputs. The selection of the software was based on the accurate and robust simulation engine, ease of linkage to GIS, data viewing facilities, graphical views and real-time control (RTC) modeling functionality.

The PS 50 portion of the model includes 12 pumping stations and two off-line storage tanks which have three RTC controlled gates to regulate filling and emptying as well as 5 RTC regulated pumps. The Hydroworks™ RTC functionality enabled the modeling of the complex operational features of the two off-line storage facilities for both existing and future alternative scenarios.

EXISTING OFF-LINE STORAGE FACILITIES

The off-line storage facilities located in the PS 50 sub-basin are referred to as Little Peak and Big Peak. These off-line storage tanks are designed to store excess wet-weather flows in the system whilst reducing the effects of surcharging and spills upstream and further downstream in the system. The storage tanks use a combination of sluice gates, pumps and control systems to automatically fill, store and empty during

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and following major wet-weather events. The location of both structures is shown in Figure 1 with further details described in the following and displayed in layout schematics in Figures 2 and 3.

Little Peak Storage Facility

The Little Peak storage tank is located adjacent to Pumping Station No.51 (PS 51) which serves an upstream contributing area of 601 ha (1484 ac) and an equivalent residential population of 8145. The storage facility comprises a below-ground tank with a maximum capacity of 4.4 ML (1.16 MG), two storage tank filling pumps that extract water from the existing pump station wet-well, force main / gravity return drain, motorized sluice gate, two elevation sensors located in the wet-well and storage tank, and a PLC unit programmed to fill, store and empty the tank following a sequence of pre-defined operational rules. The tank is also equipped with a sophisticated washing / cleaning system that activates following the filling and emptying sequence.

The 'set-points' (i.e.; pre-determined elevations that trigger pumps or gates) were determined from discussions with Baton Rouge operational / maintenance staff supported by analysis of wet-well and tank elevations recorded during dry and wet-weather periods. The following is a summary of the commands used to control the operation of Little Peak storage facility.

1. Normal operation : Pumping station maintains wet-well elevations below fill pump switch-on level. Storage tank empty.

2. Tank filling : Wet-well elevation exceeds fill-pump switch-on level and starts filling tank. Tank stops filling when; i) wet-well elevation falls below fill-pump switch-off
   ii) tank is full

3. Tank storage : Tank stores water until emptying conditions are satisfied.

4. Tank emptying : Tank empties when; i) wet-well elevation below fill pump switch-off, and
   ii) 2 hours after wet-well elevation reaches normal level.

5. Wash cycle : When tank is empty, wash cycle flushes tank and discharges effluent to the wet well.

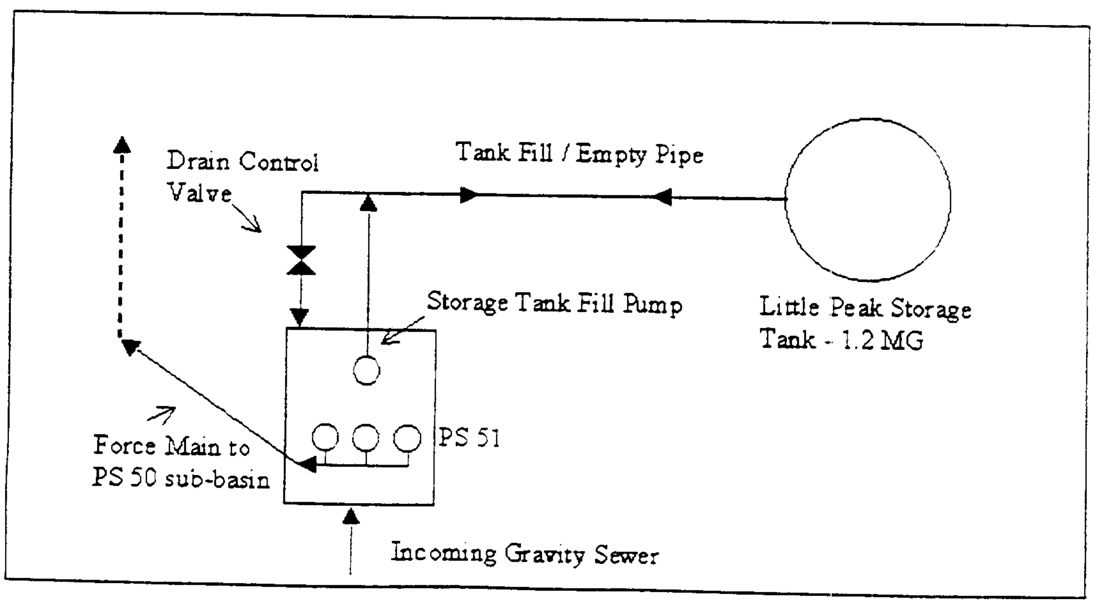

Fig. 2 - Little Peak Storage Facility Layout

Big Peak Storage Facility

The Big Peak storage facility is located downstream from Little Peak, off-line from the 900mm (36 inch) main sewer which drains to PS 50. The facility is much larger than Little Peak providing off-line storage of 17.4 ML (4.6 MG) which is filled via a gravity line and a lift pump station. The flow is controlled by a motorized sluice gate situated on a side branch from the main sewer which opens and closes depending upon system water elevations measured in the main sewer at the off-take. The sewage flows by gravity into the lift pump station then is pumped up to the storage tank. The tank elevation is above the main sewer pipe which allows the tank to empty via gravity . The emptying flow rate is controlled by a sluice gate situated on the outlet from the tank.

The tank is also equipped with a washing facility which flushes sediment and debris deposited on the tank floor during the storage period. This process operates every time the tank is utilized regardless of the storage time or the amount of water stored.

At the completion of tank emptying and washing routines a sump pump located in the base of the pumping station drains the water remaining in the pump wet well and gravity pipes back into the sewer system.

The following details the operational sequence of Big Peak storage facility.

1. Normal operation : System elevation remains below 'tank-fill' set-point.
   Storage tank empty.

2. Tank filling : System elevation exceeds tank-fill set-point and opens sluice gate.
   Flow drains via gravity to lift pump station.
   Lift pump station activates and begins to fill storage tank
   Tank stops filling when; i) system elevation falls below set-point, and
   ii) sluice gate closed, or
   iii) tank is full.

3. Tank storage : Tank stores water until emptying conditions are satisfied.
   Sluice gate is closed and lift pumps switched off.

4. Tank emptying : Tank empties when; i) system elevation falls below set-point, and
   ii) 2 hours after system elevation reaches normal.

5. Wash cycle : When tank is empty, wash cycle flushes tank and discharges effluent to the wet well.

MODEL CALIBRATION

The models were calibrated with data from the following sources:

- Flow, depth and rainfall data from a comprehensive temporary flow monitoring survey of the gravity sewers and SSO's conducted from Jan to March, 1993 involving 19 temporary in-sewer flow monitors and 5 SSO monitors.
- Flow, depth and rainfall data from permanent flow monitors and rain gauges located at key locations in the gravity system.
- Wet well depth charts from the major pumping stations
- Charts recording water levels at key locations in both storage tanks.

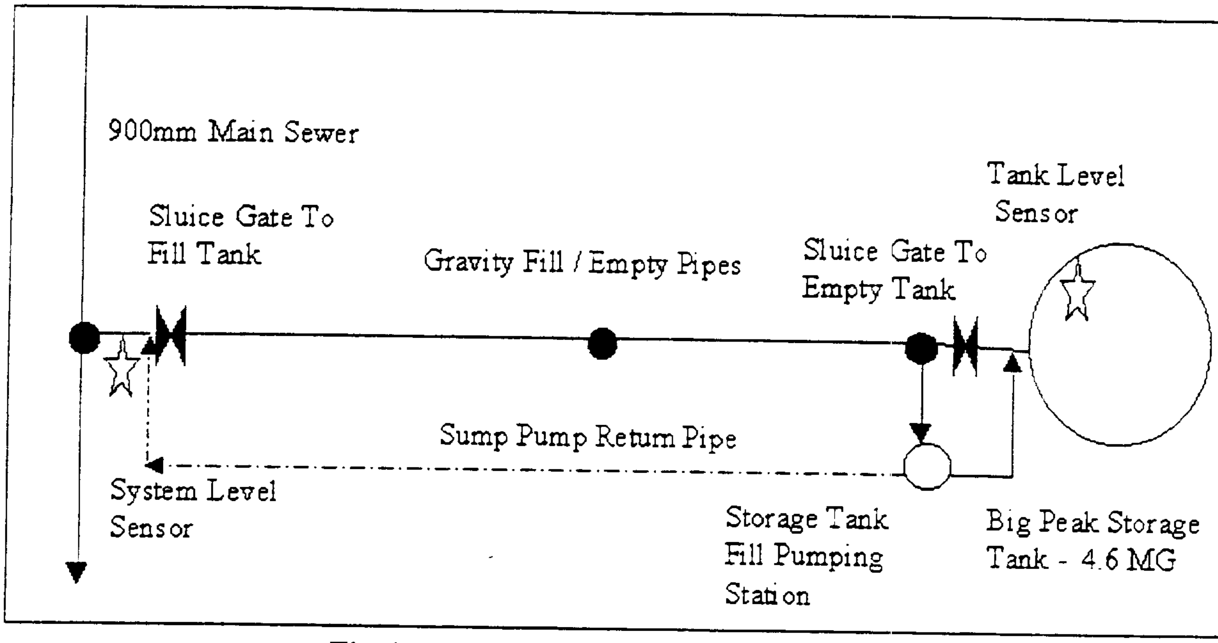

Fig. 3 - Big Peak Storage Facility Layout

To confirm the validity of the model for present day conditions the model was verified with data from the City Parish permanent flow monitoring network and the charts from the storage tanks for storms occurring in later half of 1997.

Dry Weather Calibration

The models were first calibrated to accurately simulate the weekday and weekend diurnal dry weather flow patterns using an integrated facility within the Hydroworks™ modeling software called the "Waste Water Generator" (WWG) . Advantageous features of developing dry weather flows using the WWG tool included:

- Ability to differentiate between different types of sanitary flows and ground water infiltration.
- An internal clock which references the actual dates and times of the simulation event. By this means the appropriate weekday or weekend diurnal dry weather profile is automatically applied to a historic simulation trial.
- Ready linkage to the project GIS–data management system to facilitate an effective audit trail and efficient model updating for future scenarios.

Wet Weather Calibration

Following dry weather calibration, the model was calibrated against a range of wet weather events from the flow monitoring survey conducted in 1993. Wet weather calibration was achieved using a run-off and routing algorithm within the HydroWorks™ model well suited for the simulation of I/I response characteristics. Interesting aspects of the wet weather calibration process undertaken include:

- The process for producing wet weather response hydrographs is internal to the model as opposed to the traditional method applied in the U.S. where the wet weather hydrographs are generated external to the hydraulic model.

- Routines were developed to calculate the additional surcharge storage volume available from the unmodeled pipes and manholes and to distribute and apply the additional storage to the modeled manholes.

During calibration the model results were compared to both the recorded flow and depth to assist in the differentiation between hydrologic processes and the hydraulic attenuation of flows. With the model's integrated hydrologic and hydraulic routines it was possible to calibrate the model to adequately simulate both flow and surcharge depth for a range of events.

Real Time Control Modelling

The operation of Little and Big Peak storage facilities was modeled using the real time control (RTC) feature in HydroWorks. The modeling process involved creating an RTC file containing rules, logic statements and control parameters which control the operation of the variable sluice gates and pumps according to the sequence of rules specified by the modeler.

The hydraulic model simulated the filling, storage and emptying cycles for the observed wet-weather events recorded during the flow monitoring period. To enable simulation of the operation rules to closely mimic the observed operation it was necessary to closely simulate both the flows and surcharge depths in the mains sewer.

The model results were compared with measured flow and depth data recorded in the tanks as well as at flow monitors upstream and downstream of the storage facilities for a number of different storm events. Figure 4 shows flow and depth hydrograph comparisons from flow monitor NE 15 located approximately 500m (1620 ft) downstream from the off-take to Big Peak storage tank. Note the saw-tooth pattern on the depth hydrographs resulting from the opening and closing of the sluice gate to fill Big Peak storage tank.

STORM ANALYSIS

To verify the validity of the model to current conditions a number of storms from late 1997 were simulated on the model. Simulated flow and depth data compared favourably with data from the 5 long term flow monitors located in the basin. Fig 5 illustrates flow and depth comparisons from permanent monitor SD 10 located 1000m (3200 ft) downstream of the off-take to the Big Peak storage tank

In addition the model was run with a series of historic rainfall events with average recurrence intervals (ARI's) of 1, 2 & 5 years and duration's of 2, 3, 6, 12 & 24 hours.

Analysis of the results from the verification storms and the historic rainfall series identified the following problems in the system:

- With a peak pumping capacity of just over twice ADWF, PS 50 is a major hydraulic throttle in the system and will need to be augmented if the system is to handle the large one year plus storms.
- During smaller storms, flooding occurs in a number of locations prior to the storm tanks commencing to fill.
- Due to hydraulic restriction in the gravity pipes upstream, the water level in PS 51 at which the fill pumps to Little Peak switch on can only be reached if the hydraulic gradeline is within a few feet from ground level 540 m (1770 ft) upstream of the pump station.
- Rather than being activated by the water levels immediately adjacent to the facilities, both tanks appear as though they would provide greater protection from flooding if they were activated by depth sensors strategically located near manholes that flood.

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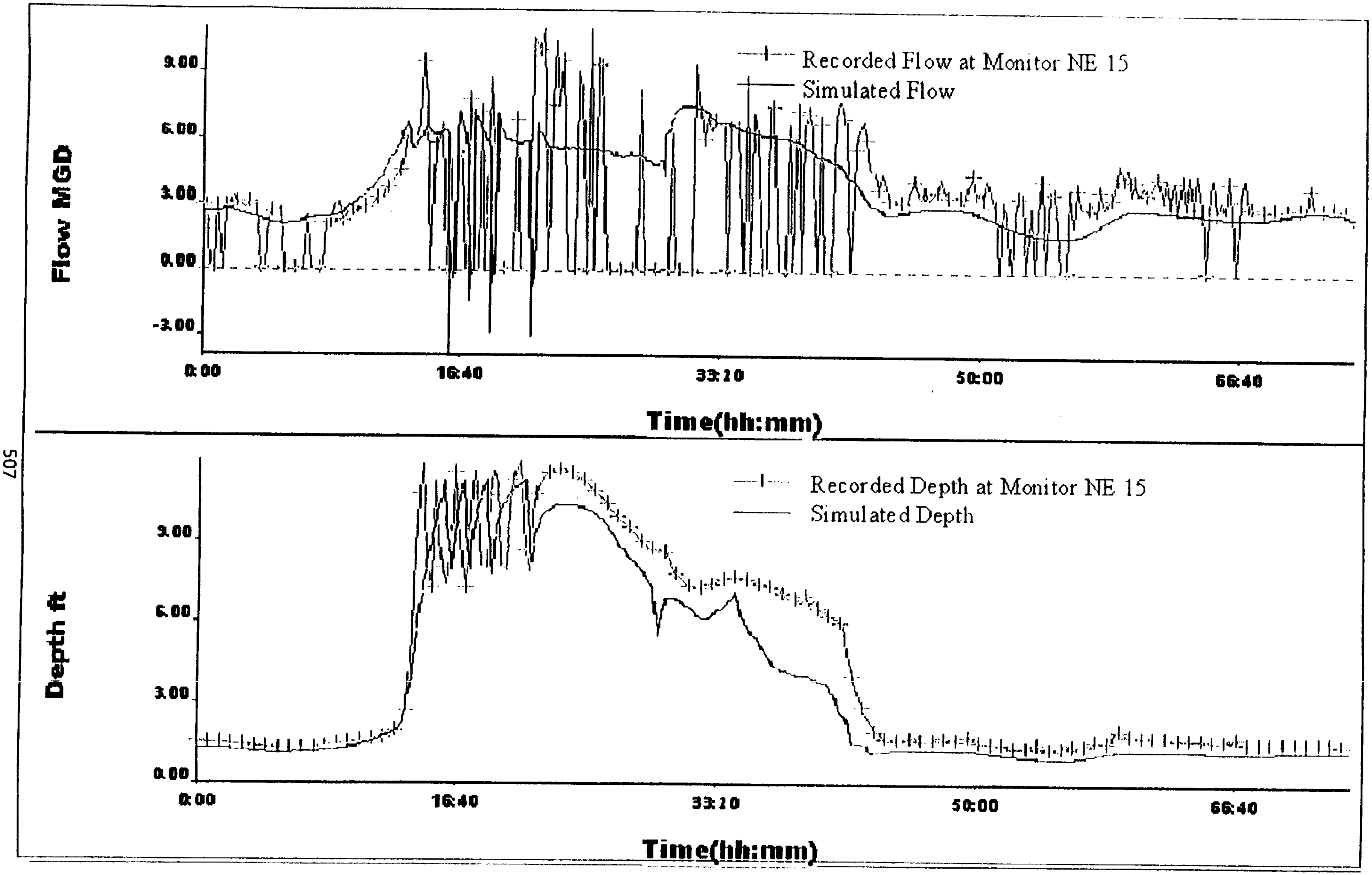

Fig. 4 Flow and Depth Hydrograph Comparisons - Storm F - 16th March 1993

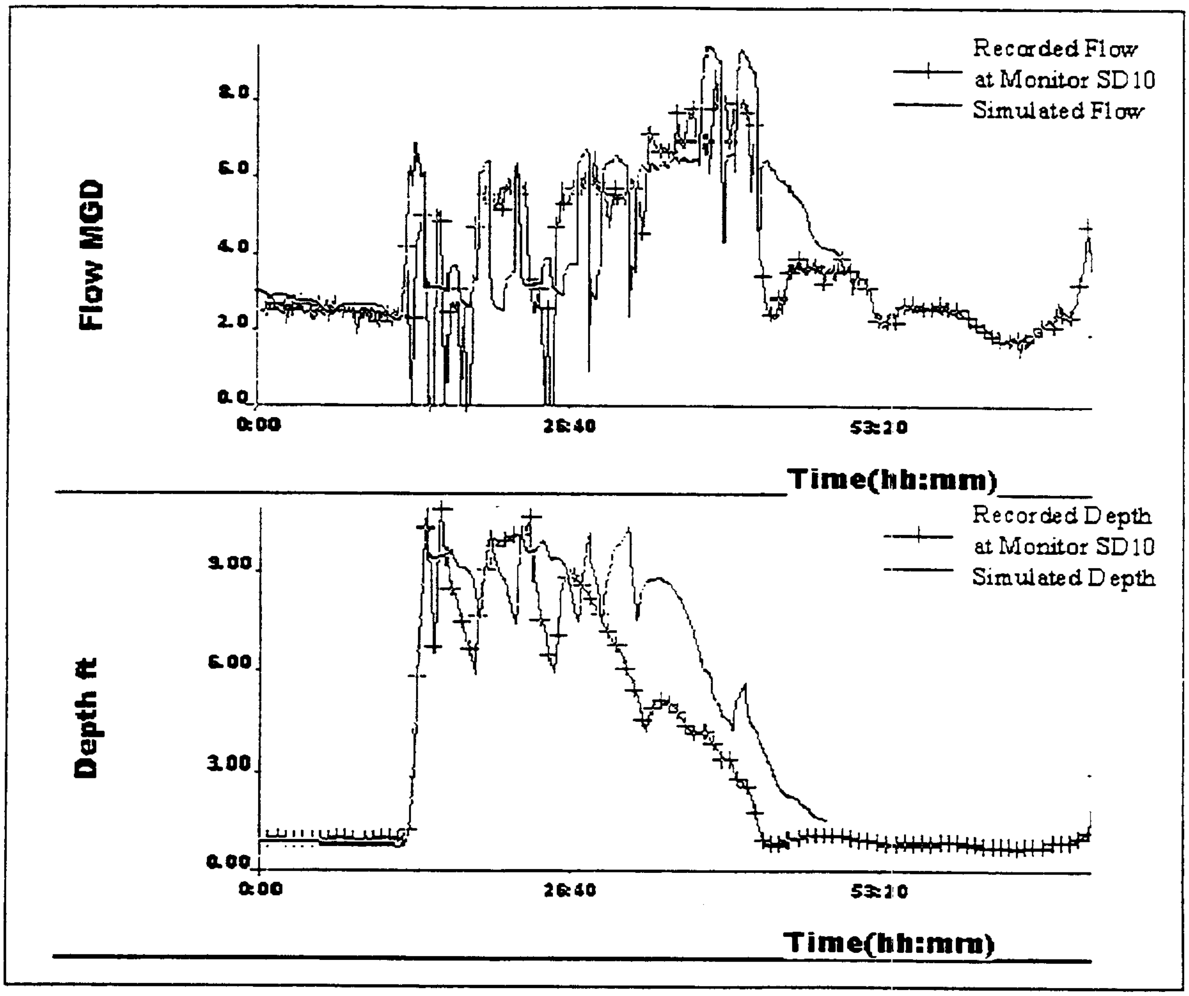

Fig 5 - Flow and Depth Comparisons - 20th December 1997

DEVELOPING SOLUTIONS AND SYSTEM IMPROVEMENTS

The calibrated hydraulic model was used to investigate various scenarios for improving the operation and performance of the sewer system. The focus of the improvements was on the reduction (i.e. frequency and volume) of spills occurring due to hydraulic deficiencies and excessive inflows entering the system. The objective of the sewer planning study was to develop working solutions that provide a significant level of improvement whilst minimizing design and construction costs.

An innovative solution currently being developed requires the modification of the existing RTC systems operating both Little and Big Peak storage facilities. The process involves relocating the 'control' sensors to critical sites within the sewer system (e.g. nearby a region where significant surcharging and spill occur), increasing storm tank pumping rates, and modifying the control algorithms to capture an increased amount of storm flow.

Initial results of these developments show reductions of spill volumes and frequencies for typical annual storms. However, large storm events generate excessive inflows, which exceed the capacity of the system causing major spills and surcharging. Further capital improvements including increased pump capacity for PS 50 and a large in-line storage tunnel are being tested using the hydraulic model.

CONCLUSIONS

1. The development of a well calibrated dynamic hydraulic model was a key component of the study. Without such a model, a clear understanding of how the system operated and behaved, along with the development of cost-effective solutions could not have been obtained.

2. Model calibration and verification are essential for developing accurate and reliable hydraulic predictions. Ensuring the model predicted reasonably accurate surcharge depths was vital for this modeling study.

3. Modeling existing and proposed RTC systems enables the engineer to predict the behavior of the off-line storage facilities and improve the system operation by making adjustments to the algorithms and sensor configuration.

USING REAL-TIME CONTROLS TO EXPLORE ALTERNATIVES TO RELIEF SEWER CONSTRUCTION

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ABSTRACT

Using real-time control (RTC) to regulate the movement of flows into and out of flow storage or diversion facilities (wet weather facilities), certain alternatives can be fully analyzed, possibly eliminating or minimizing the need for traditional parallel relief sewers. Through the use of RTC, utility owners can realize significant cost-savings when solving hydraulic capacity problems.

KEYWORDS

Real-time control (RTC), hydraulic model, SSO abatement, HYDROWORKS, wet weather storage

INTRODUCTION

While used throughout Europe, the concept of real-time control (RTC) is fairly new in the United States as a viable solution to sewer system problems. Even when real-time control has been thought of or implemented, it has commonly been in conjunction with combined sewer or storm drainage systems. Also, with the advent of more advanced, capable & dynamic hydraulic modeling software in the recent years, hydraulic modeling of potential RTC solutions prior to implementation has made RTC solutions even more attractive than ever. Due to increasing demand from the municipal and consulting community for knowledge regarding the capabilities and applicability of RTC, this paper will explore some uses and benefits of some real time controls in today's separate sanitary sewer systems by modeling them with an advanced hydraulic modeling software package.

Detailed objectives for this paper include:

- Answering the industry's need for knowledge about what real-time control is and how it might benefit collection system owners throughout the United States.
- Evaluating real-time controls and associated facility scenarios on an actual existing sewer system.
- Investigating the benefits of real-time control vs. traditional approaches in dealing with capacity problems.

Answering the Industry's Need for Knowledge about RTC

For this discussion, Real Time Control (RTC) in a sewer collection system is simply defined as the ability to manipulate various flow control structures in the collection system based upon conditions elsewhere in the collection system. The pumps in a pump station are undoubtedly the most common flow control structures found in sewer systems today.

Just like in a pump station with a float switch, Real Time Control is implemented by placing some kind of sensor where it can obtain data about the sewer system or its hydraulics. The sensor then "triggers" some kind of reaction from a control structure when the data it obtains meets certain pre-set criteria, such as a rising water level tilting a float switch enough to turn a pump on.

On one level, RTC can be applied to manipulate isolated, individual flow control structures such as constant speed pumps, variable frequency drive pumps, variable height gates, variable crest and width weirs, and inflatable dams to provide localized control of flows.

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Alternatively, RTC can be used to globally manage flows throughout an entire sewer network. A sensor can be placed anywhere in the system, and using telemetry, data from the sensor can be acted upon elsewhere in the system to restrict or divert flow, increase usage of available storage and, hopefully, stop sanitary sewer overflows (SSOs).

Why should a sanitary sewer system owner consider managing system hydraulics using RTC? This is an explanation found in the HYDROWORKS On-line Technical Documentation by Wallingford Software, Ltd.:

"As the standards for the performance of sewer systems become more stringent, engineers need better tools and techniques for planning the reduction of flooding and pollutant spillage." Real Time Control "...allows engineers to make the most of the latest in-sewer technology, in order to optimize the performance of existing sewage networks and to design more cost-effective new systems."

While experimenting with control structure locations, sensor locations and operating rules can be done without first modeling, it can result in very unsatisfactory results if a mistake is made and there still might be a more effective solution. By modeling several scenarios with a dynamic hydraulic modeling software package before implementation, many more scenarios can be developed, tested and evaluated at a fraction of the construction costs.

The scenarios that can be tried are only limited by the engineer's imagination. The HYDROWORKS RTC model provides sensors that can be placed throughout the system to sense a variety of parameters. The available parameters in the model are: flow, velocity, depth, rate of change of flow, rate of change of depth, level, rate of change of level, 10-minute average rainfall, pump state, adaptive pump control, regulator state, date-time, and the values of a variable, a lookup table, a range or a logic (true/false) record.

Evaluating Real-Time Controls

For the confines of this technical paper, the authors have selected a sample sewer system to evaluate. The sample used is a real, existing sewer system. It is projected that for the year 2020, this sample sewer system will have a problem: Several significant SSOs due to a lack of hydraulic capacity in pipes and inadequate pumping in a downstream pump station. The authors have selected a few likely scenarios for this system that have the best opportunity to eliminate or significantly reduce overflows and also utilize real time controls.

Real-Time Control Vs. Traditional Approaches In Dealing With Capacity Problems

As with all new technologies, there is a time to implement them and a time to go with more traditional methods. RTC is no different. Sometimes a larger or parallel sewer line can be constructed with open-trench methods to resolve capacity problems relatively quickly and inexpensively. Often, however, due to limited access, traffic disruption, "NIMBY" (Not in My Back Yard) attitudes, or just a large amount of sewer that would have to be paralleled, options can be limited and costs can be prohibitive.

Modeling with real time control as an alternative provides the municipality and its engineers yet another tool to discover more options. Instead of constructing long, large diameter relief lines to conduct more flow, more quickly, RTC offers the engineer the option of managing hydraulics by diverting peak flows into storage facilities or other parts of the system.

An added benefit to using RTC vs. traditional relief line approaches is that with relief lines, more flow is just passed downstream faster. That may solve a local problem, but it often passes the problem downstream. The eventual impact on downstream pipes may also warrant relief sewer construction, bigger pump stations, or worst of all, even increasing treatment plant capacity. With RTC, flows can be "managed", not passed downstream. Flows can be stored, or even diverted to elsewhere in the system that can handle it.

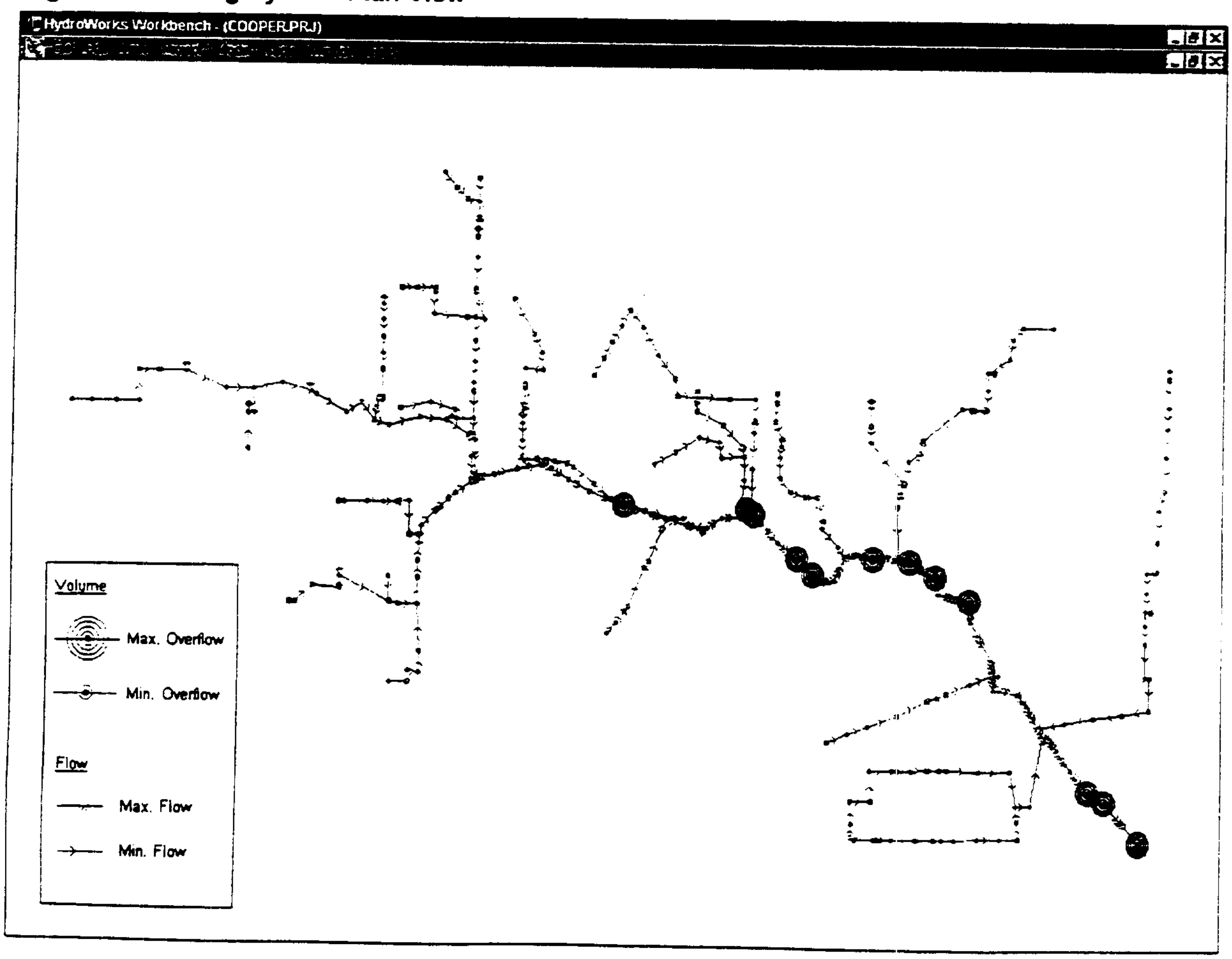
METHODOLOGY

With the power of modern day hydraulic modeling software, the simulation of RTC can be readily performed. This provides the engineer the capability to explore numerous options for optimizing flow movement in a sewer system. For this analysis, the authors utilized the HYDROWORKS™ hydraulic model with the HYDROWORKS™ RTC module by Wallingford Software, Ltd. of the United Kingdom.

The sewer system used is a separate sanitary sewer system, located in North Central Texas. The system's physical attributes, diurnal unit hydrographs, and per capita wastewater contributions were converted to HYDROWORKS from a static hydraulic modeling software, completed as part of a previous study by others. The model was calibrated using observed dry weather flow meter data and one observed wet weather event. Drainage area population was updated to estimate year 2020 conditions. All models runs reported on here are based on these parameters.

The existing system was modeled first. This model projects that the system will have numerous sanitary sewer overflows (SSOs) with significant volume in the year 2020 with the selected design storm. (See Figure 1) Conventional design approach would be to plan relief sewers to provide additional hydraulic capacity in order to carry wet weather flows and reduce overflows. This paper considered RTC measures to increase storage capacity for wet weather flows, in lieu of adding relief sewer capacity. Three different RTC scenarios were modeled to accomplish this. Each RTC scenario is configured to provide sufficient storage volume and control for reduction in SSO locations and volume, while maintaining the existing pump station pumping rate.

Figure 1: Existing System Plan View



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The modeled system is a gravity system outfalling to a large pump station and force main. The force main flow rate cannot be allowed to increase above current levels, due to significant hydraulic constraints downstream. The cost of relieving these downstream hydraulic constraints were assumed to be too great, due to large amounts of relief sewer piping that would be required in congested areas. The pump station has a total pumping capacity of 0.20 m^3/sec (4.6 MGD). Attributes of the modeled separate sewer system and the simulation design storm are shown in Table 1.

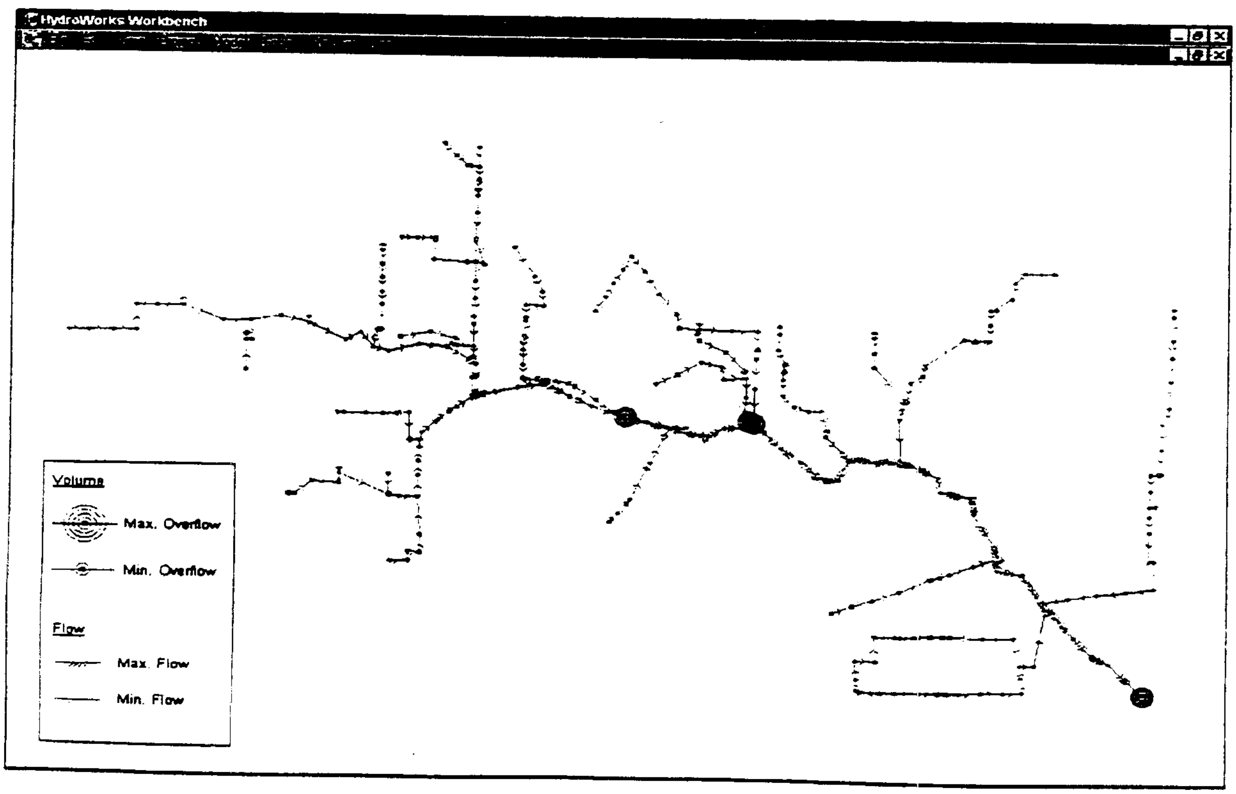
Table 1: Modeled Sewer System and Simulation Design Storm Attributes

Population:	20,968
Number of Manholes:	311
Drainage Area:	9,952 hectares (4,028 acres)
Larger Pipe Diameter:	690 mm (27 in.)
Smallest Pipe Diameter:	250 mm (10 in.)
Storm Modeled:	10 year, 2 hour
Storm Volume:	1,407,567 m^3 (371.8 MG)
Peak Intensity:	130 mm/hr (5.1 in./hr)
Total Rainfall:	86 mm (3.4 in.)
Total I/I:	4,692 m^3 (1.3 MG)
Simulation Duration:	48 Hours

RTC Scenario One

This scenario centered on a wet weather storage facility adjacent to the pump station. The facility is located in line, just upstream of the drainage basin discharge into the pump station. This location allows the storage facility to act as an extension of the pump station wet well, and subject to the pump controls located there. (See Figure 2)

Figure 2 – Scenario One Plan View

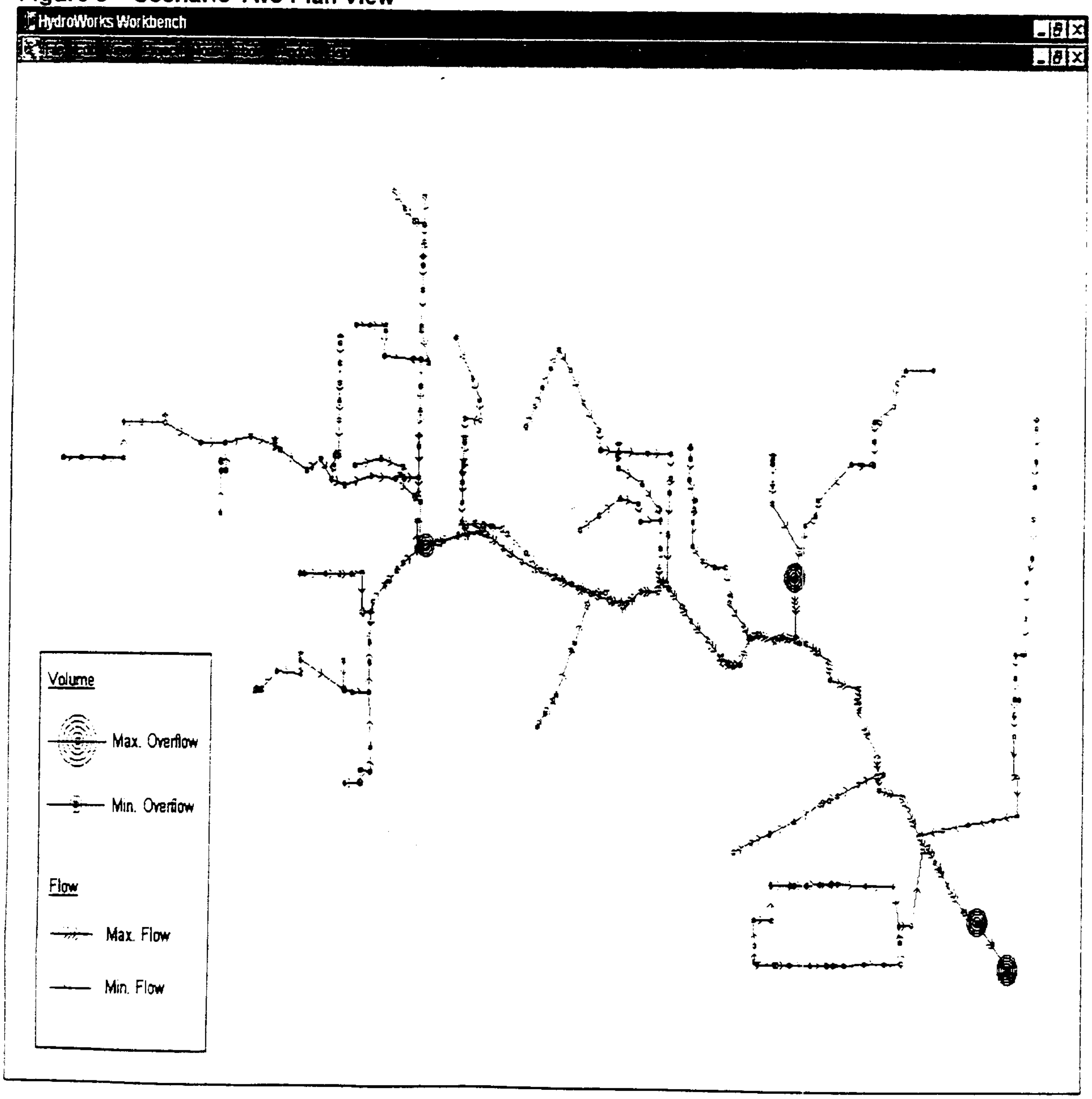


This location was chosen due to its proximity to some of the large volume SSOs in the sewer system, and that land and maintenance resources were available from the existing pump station.

RTC Scenario Two

The second scenario consisted of two in-line storage tank locations, in place of the pump station wet weather storage facility. The mid-section of this drainage area also contained several SSOs. One tank was located in the upper part of the drainage basin on the main collector line, upstream of most SSOs. The second in-line tank was located on a major branch line in the mid-section of the drainage area, just upstream of the main line and the larger SSO locations. Tank location was selected based upon proximity to SSOs, consideration for land space, and proximity to large branch flows entering the main collector line. (See Figure 3)

Figure 3 – Scenario Two Plan View

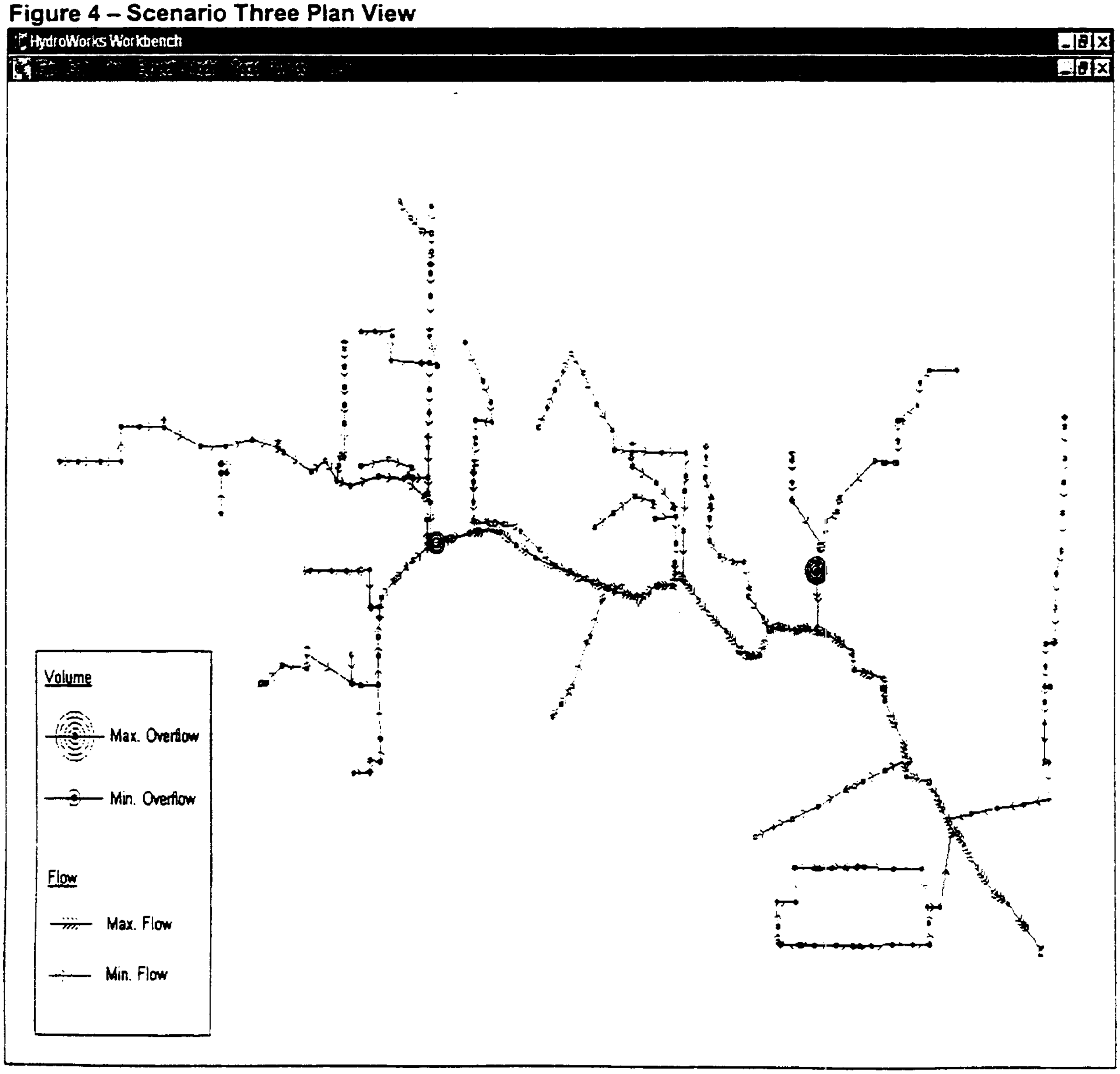


Each in-line tank had RTC gates located at the downstream end. Each gate is controlled to react to a downstream water level sensor. The sensors have been placed in locations with quick reacting hydraulic grade lines. Once the water level in these sensor points rises past the trigger elevation, the RTC gates are closed and wet weather storage volume is utilized. Each tank also has an upstream safety override sensor that reopens the RTC gate if excessive backup occurs in the sewer system upstream of the in-line tanks.

RTC Scenario Three

The third scenario combined scenarios one and two. The desired effect would be to minimize SSOs, with the combined storage volume being less than that of alternatives one and two combined. (See Figure 4)

Figure 4 – Scenario Three Plan View



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RESULTS

The HYDROWORKS™ hydraulic modeling software was utilized to simulate the existing condition, as well as the three RTC scenarios.

Table 2 displays the results of the simulation runs. Maximum discharge is the peak flow rate determined in the downstream pipe segment of the drainage basin, just prior to entrance into the pump station wet well. The results indicate that the existing system simulation and scenario two have the highest discharge, while scenario one is significantly lower. Total discharge volume is the volume discharged out of the drainage area into the pump station wet well over the 48 hour simulation duration. All simulations have essentially the same discharge volume. Number of SSOs is the count of manholes which overflow at any time during the simulation. Total SSO volume is the cumulative volume of all the overflowing manholes. The results indicate that all scenarios significantly reduce the number and volume of SSOs, compared with the existing simulation.

Table 2: Simulation Results

Scenario	Maximum Discharge	Total Discharge Vol.	# of SSOs	Total SSO Volume
Existing	0.24 m^3/sec (5.4 MGD)	19,952 m^3 (5.3 MG)	12	2,076 m^3 (0.55 MG)
1	0.10 m^3/sec (2.2 MGD)	19,676 m^3 (5.2 MG)	2	6 m^3 (0.002 MG)
2	0.24 m^3/sec (5.5 MGD)	19,886 m^3 (5.3 MG)	5	582 m^3 (0.15 MG)
3	0.21 m^3/sec (4.8 MGD)	19,900 m^3 (5.3 MG)	2	0.01 m^3 (0 MG)

The tank volumes displayed in Table 3 provide an indication of how efficiently each scenario accomplishes the goals of reduced SSO locations and volume, while not exceeding existing pump station capacity. The largest single required storage volume is the wet weather facility located near the pump station in scenario one. The smallest required storage volume is the second in-line storage facility used in scenarios two and three. Scenario two has the lowest total storage volume.

Table 3: Simulation Storage Tank Volumes

Scenario	Wet Weather Facility	In-Line Storage 1	In-Line Storage 2	Total
Existing	0	0	0	0
1	2282 m^3 (0.6 MG)	N/A	N/A	2282 m^3 (0.6 MG)
2	N/A	640 m^3 (0.17 MG)	466 m^3 (0.12 MG)	1106 m^3 (0.29 MG)
3	867 m^3 (0.23 MG)	640 m^3 (0.17 MG)	466 m^3 (0.12 MG)	1973 m^3 (0.52 MG)

The results displayed in Tables 2 and 3 provide the criteria to evaluate the RTC scenarios.

DISCUSSION

RTC Scenario One

Scenario one achieves the goal of significantly reduced SSOs while not exceeded the existing pump station capacity. This is accomplished with one large tank. A tank of this size could pose certain maintenance and "NIMBY" concerns. This scenario is most effective at reducing the peak flow rate into the pump station. Advantages and disadvantages are shown in Table 4.

Table 4: Scenario One Advantages and Disadvantages

Advantages	Disadvantages
Essentially eliminates SSOs	Largest tank volume
Does not exceed existing pump station capacity	Large footprint required
Single tank location	Highest maintenance
Outlet discharge rate is lowest of all scenarios	

RTC Scenario Two

Scenario two also achieves the simulation goal, but somewhat less successfully since there are still some SSOs in the lower reaches of the basin. The RTC gates have effectively provided storage sufficient enough to reduce SSOs (particularly those in the middle and upper reaches), while not incurring "new" SSOs upstream. However, it appears that some downstream storage is required in order to fully eliminate all SSOs. Advantages and disadvantages are shown in Table 5.

Table 5: Scenario Two Advantages and Disadvantages

Advantages	Disadvantages
Lowest total storage volume	Highest drainage basin outlet discharge; no change from existing and higher than LS capacity
Does not exceed existing pump station capacity	Reduces, but does not eliminate SSOs
Lowest maintenance	Multiple tank locations

RTC Scenario Three

This scenario also essentially eliminates SSOs, but accomplishes this goal with less total storage volume than scenario one. Most notably, the downstream storage facility at the pump station is about one-third the size of the facility in scenario one, making it less expensive and more suitable for many locations. Even though the basin discharge is not reduced as much as in scenario one, the discharge has been reduced to match the pump station pumping capacity. Advantages and disadvantages are in Table 6.

Table 6: Scenario Three Advantages and Disadvantages

Advantages	Disadvantages
Essentially eliminates SSOs	Total storage volume greater than Scenario Two
Does not exceed existing pump station capacity	Discharge greater than Scenario One
Total storage volume less than Scenario One	Medium maintenance
Drainage basin outlet discharge equivalent to LS capacity	Multiple tank locations
Footprint required less than Scenario One	

CONCLUSIONS

As demonstrated by these three RTC alternative simulations, RTC can provide an alternative to traditional approaches for handling wet weather flows in separate sanitary sewers. The three simulations have all met the specific constraints of this example sewer system: reduction in the number and volume of SSOs without exceeding the existing pump station capacity at the drainage outlet. These constraints improve the overall quality of service a utility provides, avoid simply "passing the problem" downstream, and negate the need for costly relief sewer construction within and downstream of the modeled drainage area.

Scenario one does the job, but may be unfeasible in certain neighborhoods. The RTC gates in the in-line storage tanks of scenario two provide some reduction without creating new SSOs, but as configured are unable to fully eliminate SSOs in the lower reaches of the drainage basin. Scenario 3 seems to provide an optimized combination of underground, in-line storage in the upper and middle reaches of the basin with a downstream storage facility that is almost one-third the size of the storage facility in alternative one. The results of these simulations add credence to the consideration of RTC solutions in separate sanitary sewer systems.

Modeling with real time control as an alternative provides the utility and its engineers yet another tool to discover more solutions.

ACKNOWLEDGMENTS

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REAL TIME CONTROL MODELING FOR SEWER SYSTEM OPTIMIZATION

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ABSTRACT

Flooding and overflows of untreated wastewater can occur even when there is sufficient storage in the sewer system to contain the volume of flow during a storm event. In many sewer systems, the flows are not effectively routed, failing to take advantage of available storage. Real Time Control (RTC) enables effective use of the latest technology in sewer systems modeling to optimize the performance of existing systems and to design more cost-effective systems. RTC makes it possible to determine the best locations for sewer appurtenances and the most efficient operating patterns under a wide range of hydraulic and hydrological conditions.

This paper illustrates the benefits of using RTC for flow control in sewer systems for the optimum and most cost-effective operation, with significant cost savings, and pollution reduction. The paper also demonstrates that RTC modeling enables multiple "what if" scenarios to be evaluated using hydraulic computer models of the sewer systems before investing in costly and sometimes disastrous improvements.

KEYWORDS

Real Time Control (RTC), optimization, in-system storage, overflows, SSOs and CSOs.

INTRODUCTION

Real Time Control (RTC) can be used to optimize the performance of existing systems. The optimization frequently involves the use of in-system storage in the sewer system to reduce the frequency of Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs). RTC modeling allows sewer appurtenances to be modeled, using rules which are specified by the user, to regulate flows at a location in the sewer system related to flows, depths, or rainfall intensities elsewhere in the sewer system.

RTC management of sewer systems involves the use of sensors to monitor flows continuously, telemetry to pass measurements from sensors to flow regulating appurtenances such as pumps, movable gates and weirs, and controlling devices which can change the state of appurtenances during a storm event. RTC can be applied to individual appurtenances to provide local control of flows, as well as to make global management of flows possible throughout the sewer system: a level meter at the most upstream of the sewer system may operate a penstock near the treatment works.

RTC modeling parameters can be combined to build complex rules, giving engineers the enormous scope to explore the potential storage capacity and optimal operating patterns in the sewer system. Engineers can evaluate the system under a wide range of "what if" scenarios for numerous dry and wet weather conditions by varying the duration and intensity of the rainfall, or the wetness of the catchment, or the spatial variability of the rainfall event.

By using telemetry in actual system RTC implementation, the engineer can implement a control system using local or global operating rules. This involves the installation of sensors such as rain gauges, flow and level meters, and appurtenances such as penstocks, variable level gates, pumps, or weirs to monitor and regulate flows through the sewer system.

WHY USE RTC?

As regulatory agencies tighten the rules governing pollutant discharges to receiving waters, and as the standards for the performance of sewer systems continue to become stringent, engineers need increasingly innovative and sophisticated tools and techniques for planning the reduction of flooding and pollution. RTC allows engineers to make the best use of technological advances in sewer systems modeling to optimize the performance of existing sewer systems, and to design more cost-effective new systems.

In order to design an RTC system, it is necessary to test and evaluate the different RTC measures and their impacts on the collection system. It is impractical to test the RTC measures on a real system. Applying untested RTC measures to the real system would be not only impractical, but also a high risk-investment. Different RTC strategies have to be evaluated under a wide range of conditions, including storm events of different intensities, durations and spatial variability to minimize the risk of failure when implemented on an actual system. Such conditions are impossible to generate on the actual system within a reasonable time frame. For this reason, mathematical modeling is an obvious choice and a critical part of any sophisticated and complex RTC system design. Several years of available time series rainfall data covering a wide range of hydrological conditions can be used to evaluate the RTC system prior to actual implementation.

HydroWorks and MOUSE are the only hydraulic models that have the RTC option allowing engineers to investigate possible options, such as diverting flows from one part of the system to the other utilizing a logic which specifies that if flows in a given sewer exceed a certain rate, excess flows are diverted to another interceptor sewer, or if rainfall exceeds certain intensity, certain penstock gates within the sewer system will open to divert the excess inflow to a creek or a river. RTC makes it possible to evaluate the merits of various improvement schemes to identify the most economical solutions, and testing of planned flow management strategies under fully dynamic hydraulic and hydrological conditions and control instructions for local and global appurtenances. Planning and designing the operation strategy is a vital stage in the introduction of any RTC system, and modeling is a critical part of the planning and design process.

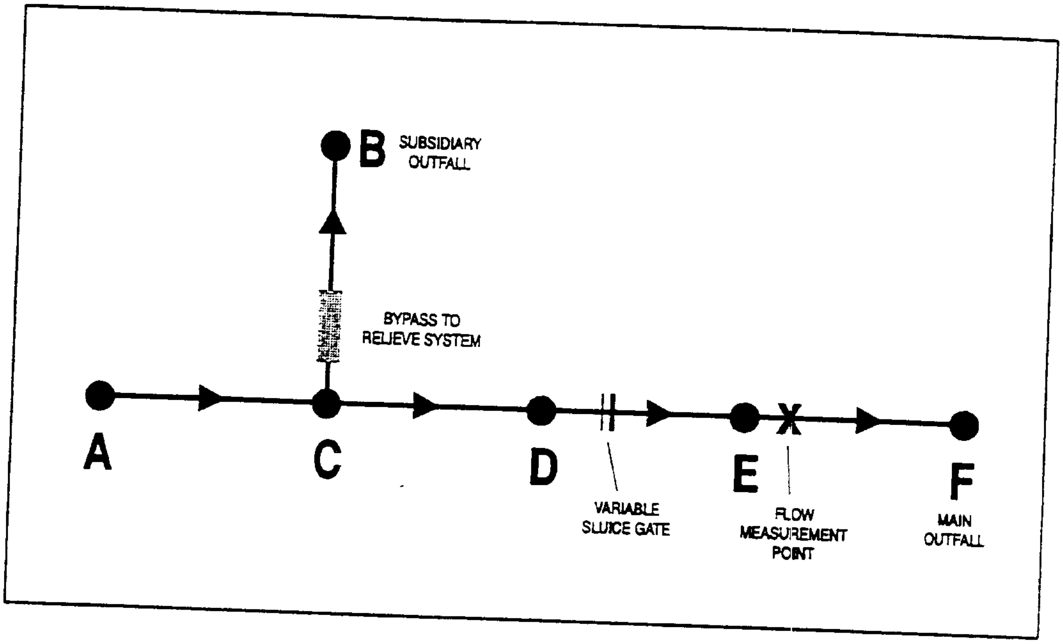
RTC SYSTEM COMPONENTS

The RTC system consists of the following components:

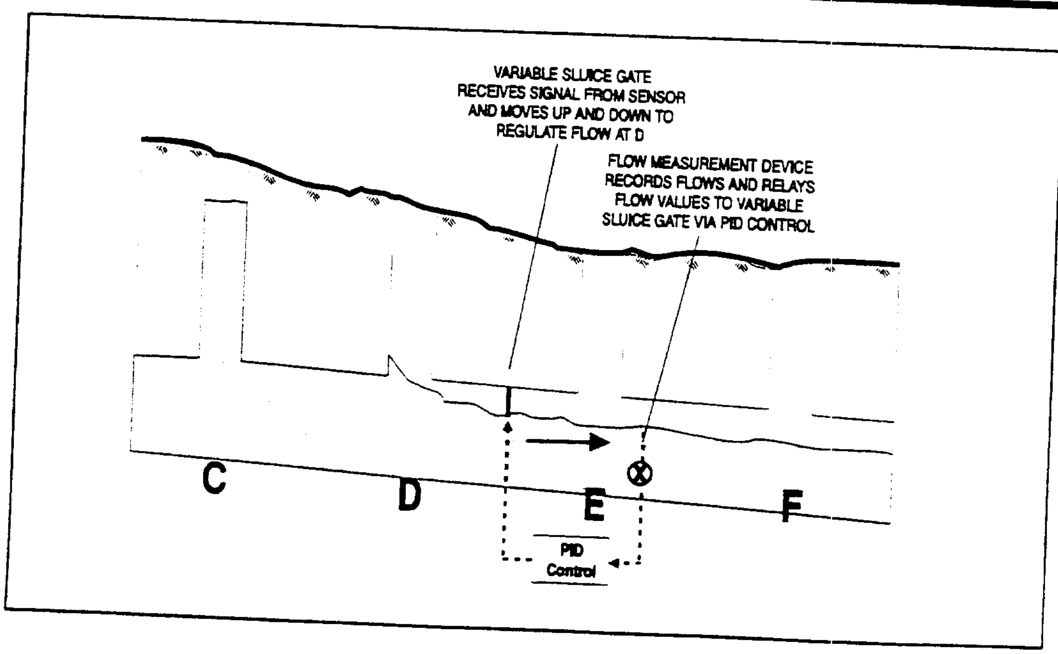
- Regulators: Control structures which can physically constrain the flows, they can be either continuous, where the variable can take any value within a permitted range such as a sluice gate, or discrete, where the variable can be only "off" or "on" such as a pump. A regulated variable is controlled by a regulator - either the physical position of the regulator, (for example the opening of a gate), or the flow at the regulator.
- Setpoint: The desired flow condition to be maintained by regulators, or the target value of the regulated variable which a regulator is to achieve.
- Range: Trigger levels for measured variables such as flow, depth, or rainfall.
- Conditions: Logical conditions which can be true or false depending on whether ranges have been triggered.
- Rules: Combinations of one or more ranges which allocate a setpoint to a regulator. An incremental rule moves the regulator by a fixed increment to either increase or decrease the setting of the regulator. A rule gives a value to a setpoint based on the value of the output condition.
- Controllers: Devices which define the detailed operation of how a regulator meets a set point.

A condition is a logical variable which has a label and a value of true or false. It can be output by a measurement range or by a logical operator, and can provide the input to a local regulator. A logical operator is a combination of logical conditions which provide an output condition.

Direct control is used where the structure is under the direct control of a regulator. For example, if the target is to control the flow to treatment works, then a discharge control would do this directly. A sluice gate can be controlled indirectly by relating the gate position to the flow through the gate.



Typical PID Controller to Regulate Flow
Figure 1



PID Control
Figure 2

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A Proportional Integral Differential (PID) controller is a method of controlling a regulator to achieve a setpoint by placing a measurement sensor at the point where the defined condition is required and using this to control the movement of the gate. The controller takes into account the rates of change of the measured variable and the regulator. For a PID controller, the measurement interval is the time step at which the controller compares the setpoint and the actual variable to set a new value of the regulator.

Figure 1 shows a PID controller for regulating flows. The objective of the PID controller is to regulate flows through sewer segment EF, by raising or lowering the variable sluice gate regulator at D, so that flows in segment EF do not exceed 1.0 m^3/s. In the hydraulic model, a sensor is placed at location E to measure flows through sewer segment EF. A PID controller uses the information from this sensor to vary the opening of the sluice gate to achieve the setpoint flow of 1.0 m^3/s in sewer segment EF. At the next time step during the simulation, the PID controller again checks the flow through segment EF and adjusts the position of the sluice gate accordingly to maintain the flow through segment EF at 1.0 m^3/s. This process is repeated throughout the simulation at each time step. This example demonstrates how a PID controller can be used to evaluate the backwater effects caused by regulating flows to the treatment plant at 1.0 m^3/s in sewer segment EF. The excess flow can be backed up in the sewers upstream from the variable sluice gate or discharged through the bypass in segment CB.

The combination of RTC rules gives engineers the ability to investigate multiple options of optimizing the operation of the sewer system.

For the PID controller described, a maximum and minimum range is defined in the RTC file. The range for the sensor is used as a scaling factor for the variable E, which forms a part of the equation used by the PID controller.

$$E = \frac{Observed - Setpoint}{Range} \qquad (1)$$

Where:	E	=	Scaling factor for measured variable
	Observed	=	Value from the sensor
	Setpoint	=	Value to be maintained (1.0 m^3/s)
	Range	=	Trigger levels for measured variables

The equation used by the PID controller to calculate how much change to make to the operation of the regulator is given by equation 2:

$$\Delta S = P\ (E + I\int E dt + D\frac{\partial E}{\partial t}) \qquad (2)$$

Where:	ΔS	=	Action to be performed by regulator
	P	=	Proportional coefficient
	E	=	Scaling factor variable (See equation 1)
	I	=	Integral coefficient
	D	=	Differential coefficient

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DATA REQUIREMENTS

The data required for defining RTC facilities in HydroWorks hydraulic model for example are the physical structure geometry and the operating limits. The physical structure of the regulator and the operating limits are defined with the network inventory. The sensors and control rules are described in a separate RTC file. For a regulator, the data required may consist of crest level of a variable crest weir, width of the variable sluice gate, height of gate (sluice gate or penstock), vertical opening of the gate, and maximum or minimum discharge. An initial value of the regulated variable can be defined which gives the initial state of the regulator. The minimum and maximum settings, the speed or the rate of change of the regulated variable, and the thresholds of the regulator can all be defined in the RTC file. If the change which is to be made by a regulator in a time step is below this threshold, the action will not be performed.

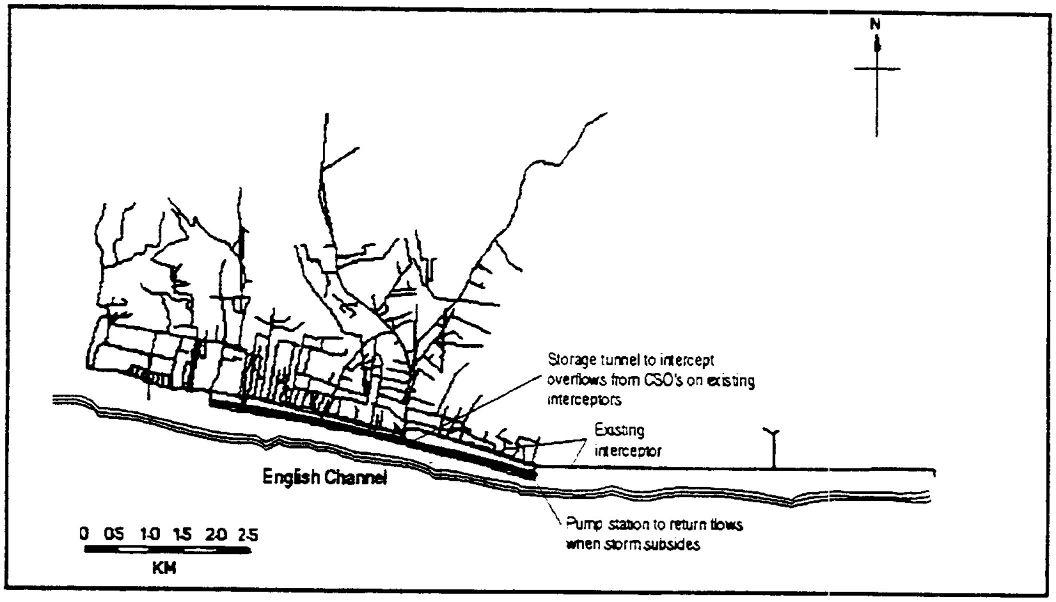
RTC APPLICATIONS

During the past few years RTC has been emerging as an alternative approach to reducing CSOs, SSOs, and pollution problems. Although there are still only a few applications of RTC in collection systems throughout the world, on many projects the cost of RTC system has been found to represent only a small fraction of the cost of constructing such alternatives as parallel or replacement sewers, or new storage facilities. Sewell and Schultz[3] in 1986, found that the cost of developing an RTC system would be between \$0.21 and \$0.31 per gallon per year, while the costs of building storage facilities to provide equivalent reduction in CSO would be between \$1.50 and \$2.00 per gallon per year. Examples of RTC applications in system optimization are:

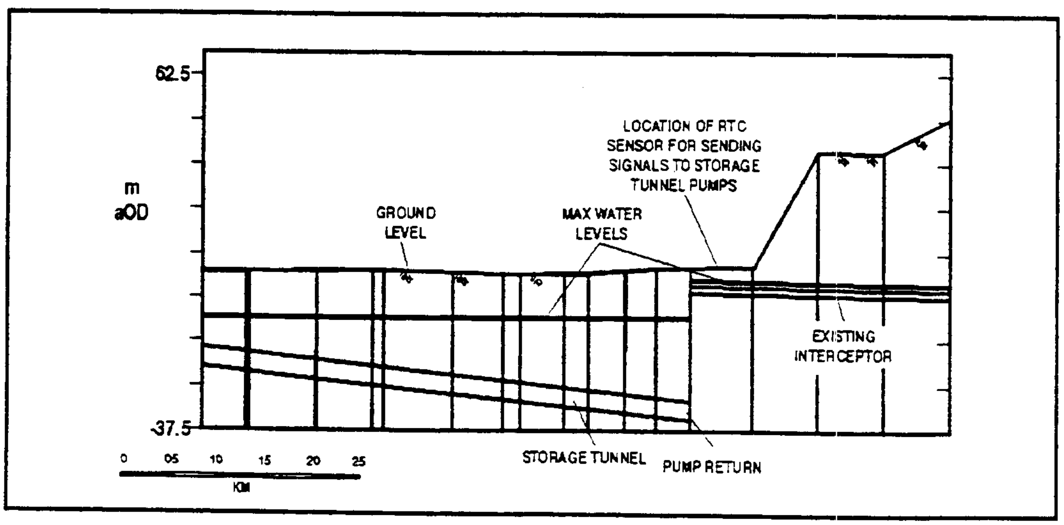
- Seattle, WA - Control of flow in sewer system to reduce CSOs.
- Brighton, England - Control of flow from a storage tunnel to an existing interceptor.
- Bradford, England - Management of numerous storage tanks and CSOs.
- Bilbao, Spain - Interceptor management to minimize pollution.
- Paris, France - Management of CSOs and flows through to the treatment works.

Brighton is a coastal town and a popular holiday resort in southern England. The existing interceptor sewer, which runs along the beach, is overloaded during wet weather, causing discharges to sea. In order to alleviate the impact of CSO discharges, a 150,000 m^3 storage tunnel was to be constructed along the beach to intercept flow from eight CSOs during wet weather. The intercepted flows are to be returned to the existing interceptor from a pumping station located at the outfall of the 5.1 km storage tunnel when the storm subsides. The HydroWorks model of the sewer system developed for this analysis includes the RTC option, which allows the control system of the outfall pumping station to be modeled. Thus, the return of flows from the storage tunnel to the existing interceptor is realistically represented in the model. The extent of the system serving approximately 250,000 residents is shown on Figure 3. Figure 4 shows the longitudinal profile of the storage tunnel, the location of the pumping station to be controlled for the optimum utilization of the storage tunnel, and the location of the RTC sensor which triggers the operation of the pumping station. Figure 5 shows the return pump which turns on to begin emptying the storage tunnel when spare capacity becomes available in the existing interceptor. Spare capacity becomes available when flows in the existing interceptor fall below 3.0 m^3/s. In effect, the RTC system involves maintaining flows to treatment at 3.0 m^3/s. Figure 6 shows how flows to the treatment plant are maintained through pumping from the storage tunnel whenever there is capacity available in the interceptor. The objective of the study is the RTC of return pumping from the storage tunnel to minimize: pumping; flooding; pollution; and combined sewer overflows. The RTC provided a platform for studying a range of options for improvement of the sewer system, allowing full evaluation of the performance of the storage tunnel and the hydraulic performance of the existing sewer system. This enabled the potential investment in the sewer system to be tested thoroughly so that cost-effective solutions could be confidently developed. The following are the main benefits of the Brighton RTC modeling:

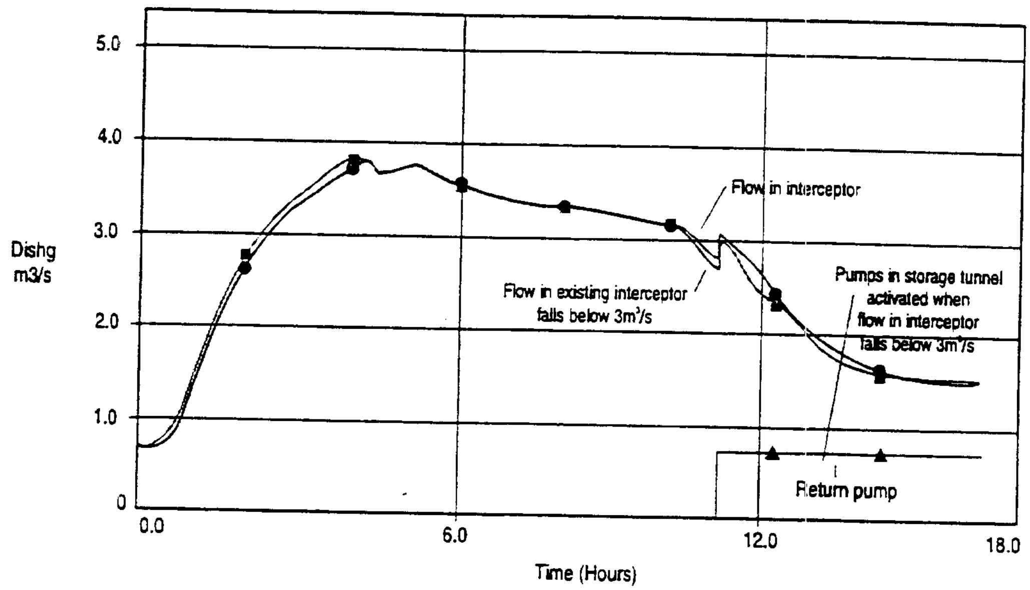
- Optimizing in-system storage on existing interceptor and new storage tunnel facility.
- Equalizing and maintaining flows to treatment at 3.0 m^3/s.
- Preventing surcharge conditions in the existing interceptor sewer.
- Minimizing the number and volume of overflows from the storage tunnel.
- Optimizing the operation of the outfall pumping station on the storage tunnel, thereby minimizing energy consumption of the pumping station.



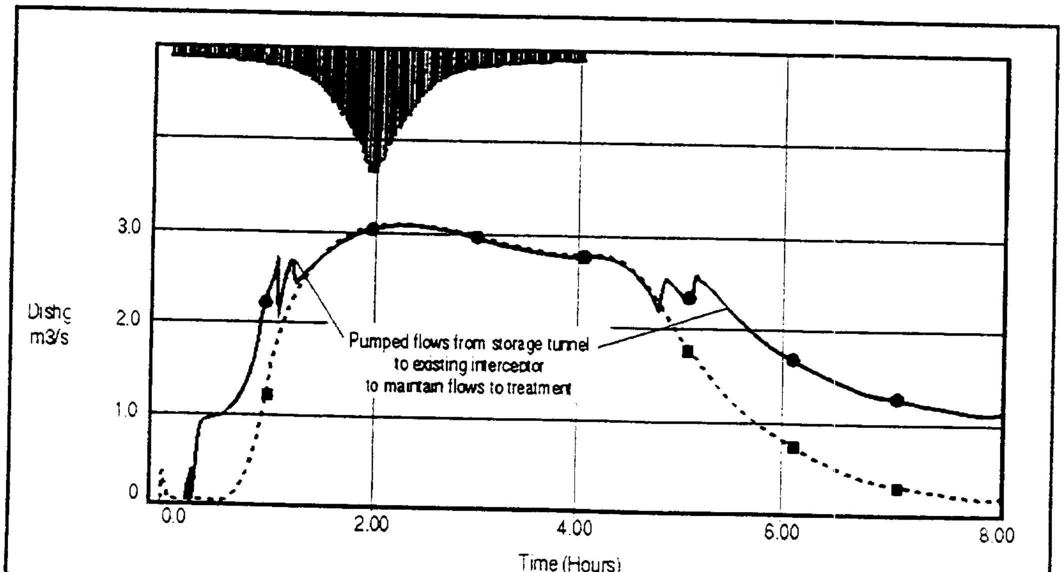
Optimization of storage tunnel using RTC
Figure 3



Location of RTC sensor for storage tunnel optimization
Figure 4



Pumps activated in storage tunnel with "spare" window in existing interceptor
Figure 5

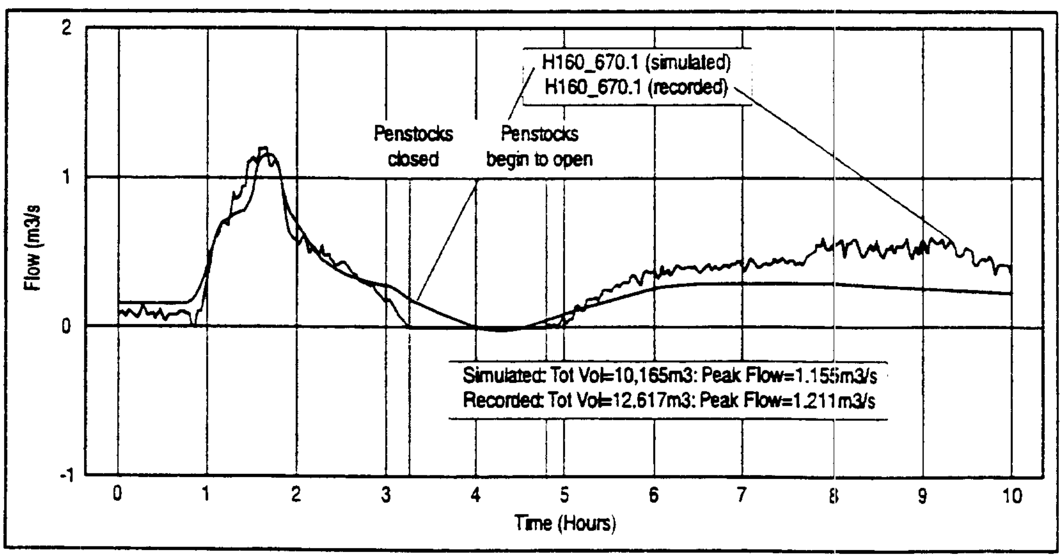


RTC for maintaining flows to treatment
Figure 6

Many existing collection systems have limited RTC systems, such as variable discharge pumping stations, variable sluice gates, and automated penstocks. The objective of such systems is to adjust pump speeds, and gate positions during a storm event to increase the use of in-system storage in response to changes in rainfall patterns and flow conditions within the sewers. In most real time control systems, the decision making process is computerized. In a computer-controlled system, a pre-programed computer decides when and how regulators are to be operated, though it is supervised by operators and can be manually over-ridden at any time. During a hydraulic model calibration of such systems, it is important to accurately represent the RTC system and calibrate the operation of the RTC system against operational data, providing confidence in the operation of the RTC system, prior to using the model for hydraulic evaluation. The calibration is achieved using a hydraulic model with the RTC option. During model calibration for the Derby Improvement Strategy Project in England, it was necessary to use the HydroWorks RTC module to accurately represent the real time behavior of penstocks protecting the treatment works at the outfall of the sewer system. The penstocks are closed when the flows to the treatment works exceed the plant capacity. When the gates are closed, the interceptors upstream from the treatment works are utilized for storing excess flow until the storm subsides, and the gates begin to open.

It can be seen from Figure 7, that the penstock gates are closed at approximately 3 hours into the storm event and remain closed for about 2 hours. The gates begin to open about 5 hours into the storm event.

By using HydroWorks RTC, the real time behavior of the penstocks was accurately modeled during model calibration, thus gaining valuable insight into the operation of the penstocks, before using the model for further evaluation of the sewer system. Without accurate representation of the RTC rules in the model, it would not have been possible to realistically predict the behavior of the penstocks, and to recommend improvements to the system.



RTC for modeling penstocks protecting sewage treatment works
Figure 7

CONCLUSIONS

Real Time Control (RTC) modeling enables sewer system controls, such as penstocks and movable weirs, to be modeled in a sophisticated manner, with consideration to their real time functioning. Even if the sewer system has adequate capacity to contain the flow, flooding and spills of untreated wastewater can occur. In many systems, the flows are not effectively routed, failing to take advantage of the storage capacity in the system. RTC enables effective modeling techniques for planning preventive measures against flooding and pollutant spills and for optimizing the performance of existing systems, as well as aiding in the design of more cost-effective and efficient systems. It enables the selection of the best locations and operating patterns for sewer system appurtenances under a wide range of hydraulic and hydrological conditions. RTC modeling requires the use of accurate and sophisticated models to a much higher standard than ordinarily used for sewer studies. The governing equation of the hydraulic model must be St. Venant's flow routing unsteady state equation, capable of simulating full backwater and attenuation in the sewer system. Of the major hydraulic modeling software programs available (HYDRA, HydroWorks, MOUSE, and SWMM), only MOUSE and HydroWorks have full RTC capability. It is not only impractical, but also a high-risk investment to implement an untested expensive RTC system in a collection system. Thus, modeling provides the obvious choice for testing the RTC system prior to implementation, enabling the investment in the sewer system to be throughly tested so that cost-effective solutions are confidently developed. The cost of developing an RTC system is usually between \$0.21 and \$0.31 per gallon per year, while the costs of building storage facilities to provide equivalent reduction in CSO could be between \$1.50 and \$2.00 per gallon per year [(3)]. Thus, the cost of RTC systems represent only a small fraction of the cost of constructing such alternatives as parallel or replacement sewers, or new storage facilities.

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DEMYSTIFYING SOME ASPECTS OF REAL TIME CONTROL APPLICATIONS FROM THE DESIGN PHASE TO IMPLEMENTATION

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ABSTRACT

Real Time Control (RTC) is viewed more and more as a very effective and inexpensive solution for CSO control, by maximizing the use of in-line and off-line retention, and wastewater treatment capacity. While Municipalities and Water Commissions are realizing that RTC would be advantageously applied to either reduce CSO and/or reduce the size of their CSO control infrastructures, few are well prepared to integrate this technology in their overall plan, the different type of RTC system could adapt better to their situation, and how it can be implemented.

Real time control systems can take many configurations, from local control, with or without supervision, to global integrated automated predictive real time control. Each of these configurations is best applied to specific network conditions. The potential advantage of each configuration must be evaluated against the level of sophistication and automation that can be supported locally. A more centralized, integrated, and predictive system, improves the gain from the management of a complex network of stations, but entails the implementation of more diverse software and equipment.

Asseau BPR has been involved in many studies and application of CSO control projects that involved RTC applications since more than ten years in the city of Laval (Canada), the Quebec Urban Community (QUC, Canada), the Ile-de-France Region (France), the Northeast Ohio Regional Sewer District (Cleveland, Ohio). While realizing the QUC RTC system in the early 1990s, we realized tools to analyze RTC operation were unexistant and available RTC technology were deficient in many respect when applied to sewer network applications. Compared to most industrial operations, the context of RTC of sewer network is quite different: local stations are spread over a large territory, working conditions are septic and highly corrosive, and events highly variable in time and space.

This is the reason why Asseau-BPR initiated a five year R & D project, ending in June 1998, to develop methods, software, and technology specifically designed to realize CSO control projects with coherent and integrated tools that cover all phases from the monitoring, diagnosis and design phase, to implementation of real time control. We present here the technological evolution that lead to the development of some of these tools and technology and now make real-time control a more feasible and accessible solution than ever before.

KEYWORDS

Combined Sewer Overflow control; Real-time control; Long term CSO planning.

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INTRODUCTION

Real Time Control (RTC) is viewed more and more as a very effective and less expensive solution for CSO control, by maximizing the use of in-line and off-line retention, and wastewater treatment capacity. While Municipalities and Water Commissions are realizing that RTC would be advantageously applied to either reduce CSO and/or reduce the size of their CSO control infrastructures, few are well prepared to integrate this technology in their overall plan, the different type of RTC system could adapt better to their situation, and how it can be implemented.

Real time control systems can take many configurations, from local control, with or without supervision, to global integrated automated predictive real time control. Each of these configurations is best applied to specific network conditions. The potential advantage of each configuration must be evaluated against the level of sophistication and automation that can be supported locally. A more centralized, integrated, and predictive system, improves the gain from the management of a complex network of stations, but entails the implementation of more diverse software and equipment.

The potential of RTC implementation must be assessed rapidly, as another element of a CSO plan alternative. This was shown extensively in the previous WEF Wet Weather Specialty Conference in Quebec City (June 1996). The most difficult element to define to assess the potential application of RTC, is to evaluate the control rules or algorithm that will best regulate the flow for specific network layouts. Hence, it is most valuable to have within a hydraulic model not only the capacity to simulate dynamic flow control devices, but also an engine that can find, through an optimization process, the best control logic for each configuration that is tested.

When RTC potential is assessed, its implementation must be resolved and must translate the potential into reality, which involve the following elements: the control strategy; the configuration of the control system; each element of a control system; the choice of technology; the robustness required; etc.

Asseau BPR has been involved in many studies and application of CSO control projects that involved RTC applications since more than ten years in the city of Laval (Canada), the Quebec Urban Community (QUC, Canada), the Ile-de-France Region (France), the Northeast Ohio Regional Sewer District (Cleveland, Ohio). While realizing the QUC RTC system in the early 1990s, we realized tools to analyze RTC operation were unexistant and available RTC technology were deficient in many respect when applied to sewer network applications. Compared to most industrial operations, the context of RTC of sewer network is quite different: local stations are spread over a large territory, working conditions are septic and corrosive, and events highly variable in time and space.

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A SURVEY OF EXISTING REAL-TIME CONTROL SYSTEM

Real-time control systems (RTC) applied to the control of sewers and CSOs has been developed since as early as the late 1960s. The idea is not new. At the time, RTC seemed a very worthwhile venture to reduce the risk of flooding and the impact of combined sewer overflows. Because of the risk involved in developing these new systems, the US Environmental Protection Agency helped finance some demonstration projects.

The first US EPA demonstration project in this field started in 1966 and was implemented in Minneapolis-Saint-Paul. Other projects followed. In the United States, nine real time supervision and control projects have been found in the literature. Most of them were initiated in the 1970s and implemented in the 1980's. Among them we have : Seattle, Wa; Rochester, NY; Cleveland, Oh; Detroit, MI; Chicago, IL; Milwaukee, WI; San Francisco, Ca; Minneapolis-Saint-Paul, MI; Lima, Oh.

All these projects have implemented supervisory systems and, except for Seattle, all their control systems operate gates, inflatable dams, and pump stations with local reactive control logic. Seattle is the only remaining automatic central control system in operation, although many others had planned to implement such centralized control. Reasons for not going forward with central control include : unreliable communication (Cleveland); hardware failures (Detroit); operators resistance (Rochester, Detroit); the control system never worked as planned (Minneapolis-Saint-Paul); abandon (San Francisco). Reference (Schilling, 1987; Gonwa and Novotny, 1993).

In Europe, real time control projects lagged behind the North American experiences. It was not until the 1980's that such project emerged, although from the few experiments of the 1980's, such as in Hamburg (Germany) and Seine-Saint-Denis (France), the impetus has never vanished, and has even gained momentum in recent years.

In France, there are presently 8 real time control systems in operation in Bordeaux, Hauts-de-Seine, Marseilles, Metz, Nancy, Seine-Saint-Denis, Val-de-Marne, and the Paris agglomeration. In Germany, we found 4 real time control projects (Bremen, Hamburg, Munich, and Stuttgart), while in Switzerland there are also 4 RTC systems in operation (Berne, Fribourg, Geveva, Lausanne), in Sweden one (Göteborg), and in Denmark (Copenhagen). The objective of these systems is mostly for flood control, although the most recent applications are for CSO control. The configuration of these systems are quite similar to those in the U.S. : they all have central supervisory systems, and except for four applications, all have implemented local reactive control rather than centralized control. This list is certainly not exhaustive and will grow steadily in the future.

CRITERIA FOR NEW REAL-TIME CONTROL TECHNOLOGY

Since the development of the first RTC systems, the computer and information technology has taken a giant leap in processing capacity, in user-friendliness, in accessibility, robustness and in reliability. This has helped increase the capacity and reliability of all elements of RTC systems, most notably in the speed and memory of local stations, of telecommunications systems, and of central computing and polling capacity. Rapidity of processing is key to many real time control projects. Where concentration time is small, decisions have to be made rapidly, say each 5 minutes, and this for all control sites.

Many of the original technological hindrances in implementing RTC systems now form part of the folklore of the past, although there still remains some deficiencies to be addressed. Technology failures are still present in any system. Hence, often in early systems, many RTC systems were never put into operation because everything had to be in perfect order before it could properly function. Because of the multitude of components involved, equipment failures occur. Instead of overlooking this aspect, or declaring forfeit before trying, we now realize that RTC systems must handle downgraded modes that is, still perform when for example, a sensor or a local station is not responding, when some data did not reach the central, when a gate is blocked, when sensors send erroneous or diverging data, etc. Reliability is also built into a RTC system by applying data validation – not only data filtering – , and by adding some redundancy in the most crucial places. The reliability of RTC systems is best analyzed during the design phase. At that stage, it is crucial to test the effect of the loss of each component in the system or their malfunction. Risks must be assessed and addressed at an early stage.

Data management has also evolved much. Now, huge amounts of data can be processed and stored in real time, data organization has changed from the past linear file format, to relational database organization and even object oriented databases. Hence, data can be easily stored, organized and accessed, during and after events. This improves reaction time during events and the capacity to analyze and improve control performance based on past events. To do post event analysis, it is best if the on-line control software can be the same as the design, or off-line, software, hence more readily ensure that what we see during the design is what we get during operation. This capacity to continuously improve the performance of control can be best approached when the control logic software is used both for analysis and for operation.

The capacity of local stations have also improved much. Local PID units have more memory, they can be programmed in C language, they can handle more data, and be left unattended for longer periods of time. Hence, the control logic can be decentralized a lot more than few years ago. And because much information is better accessible at the local level, new real time control system configuration must take advantage of this.

When considering central control, telecommunications speed and reliability are key to the whole performance of the RTC system. Decision making is based on the accuracy and reliability of field monitoring data, on information on the state of the system. Furthermore, control set points are transmitted back at the flow regulation stations at each time step. The pressure on the telecommunication system makes it difficult not to develop new telecommunication protocols and management programs to find an equilibrium between reliability and speed of transmission.

We will see in the next section how it is possible to address these criteria to design and develop a family of integrated tools for real time control design and operations.

A COHERENT AND INTEGRATED APPROACH TO RTC

A the end of the 1980's and beginning of the 1990's, Asseau-BPR was involved in two CSO control design projects in Quebec : for the Quebec Urban Community (QUC) and the city of Laval. Both these systems were good candidates for introducing real time control. In Quebec, a centralized system seemed to yield better results, while the city of Laval could initially do with local reactive controls. At the time, no hydraulic software represented dynamic regulation. To analyze RTC operation, we asked the National Research Institute (INRS-Eau) to developed a *non* linear simulation-optimization model that could rapidly simulate and optimize central dynamic control and be put into operation. This system was custom made for the QUC application. For modeling local reactive control in the Laval project, we limited our works to programming local reactive logic and integrated the module into SWMM.

The more we advanced in the design of these two systems, the more we found we could not readily find systems that could well adapt to the kind of specifications we developed to make these RTC systems work properly with all the robustness and performance we expect. Furthermore, we recognized the great potential of RTC applications to reduce CSO control costs and the need to develop an integrated system that could be applied to many applications elsewhere, save money and time in its development, and not to start anew everytime.

We then initiated in 1992, a $ 10 million R & D project. Half of the funds were attributed to the development of sewer analysis and CSO control plan design methodologies and software – among which, a standardized diagnosis methodology, a simulation-optimization software for CSO control plan development including real time control operation aspects. Another important part of the project consisted of real-time control systems components, such as local stations configuration, control programs, data validation programs. Also, telecommunications protocols, communication management software, and speed and reliability tests during storm events. Finally, real time control database, and configuration of supervisors. Most of these components have been completed and tested in the realization of projects (Ile-de-France, QUC, Laval).

We describe below the main characteristics of the resulting integrated system. This will show how we address some of the problems identified in some of the existing RTC systems presently in operation. The integrated approach using system called MED, for Minimization of Effluent Discharge. Each components or modules have been given names addressing the affiliation to MED. *Just keep in mind that solution is based on approach, technologies, and experience; modeling tools are like pipe wrench for a pipe fitter, only a tool.*

CSO control design tools

The design of a CSO control long term plan is performed in four complementary phases:

1. Characterization of the existing network
2. Diagnosis of the existing CSO problem, usually through modeling and calibration
3. Design of a CSO control strategy (long term plan)
4. Tests of the performance of the control strategy.

This process involves many different specialists and the processing of an important amount of data.

Adding treatment, transfer, or retention capacity to control CSOs can be very costly. Therefore, it is essential to ensure maximum use of the existing system and any additional facilities needed to comply with the control requirements. Real time control proves to be a very efficient and economic solution whenever some capacity transfers within a sewer network submitted to heterogeneously distributed real rainfall events are possible.

Furthermore, it is most advantageous to be able to design, test, and operate a real time control system with the same tool. Conceptually, the system can be compared to a robot assembly line. At each stage of the assembly line, each robot produces an action which adds a sub-part to an object constructed from a succession of robot action. When the process needs to be modified, system engineers design new routines and test them off-line with dedicated simulation tools. System efficiency can be best adjusted off-line and implemented whenever it is fine tuned. Necessarily, the simulated program is the one to be implemented in the assembly line. The same design and implementation process applies to the CSO control field. This is also why, off-line simulation capabilities are useful even after the implementation of real-time control in order to learn from experience and continuously fine tune the control procedures. This concept was retained in the development of MED-SOM, a linear simulation-optimization model software used for the design optimization of CSO control long term plans and the operation of RTC systems. MED-SOM can simulate and optimize the main flow regulation control modes that is, static control, local reactive control, and global predictive control. (See Colas, 1998 for more information on MED-SOM) *MED-SOM is a design tool, connected to your preferred modeling software (MOUSE, HYDROWORKS, SWMM, XP-SWMM, which can be used as real time decision making tool, but does not keep your organization as a slave.*

DIAGNOSIS AND DESIGN

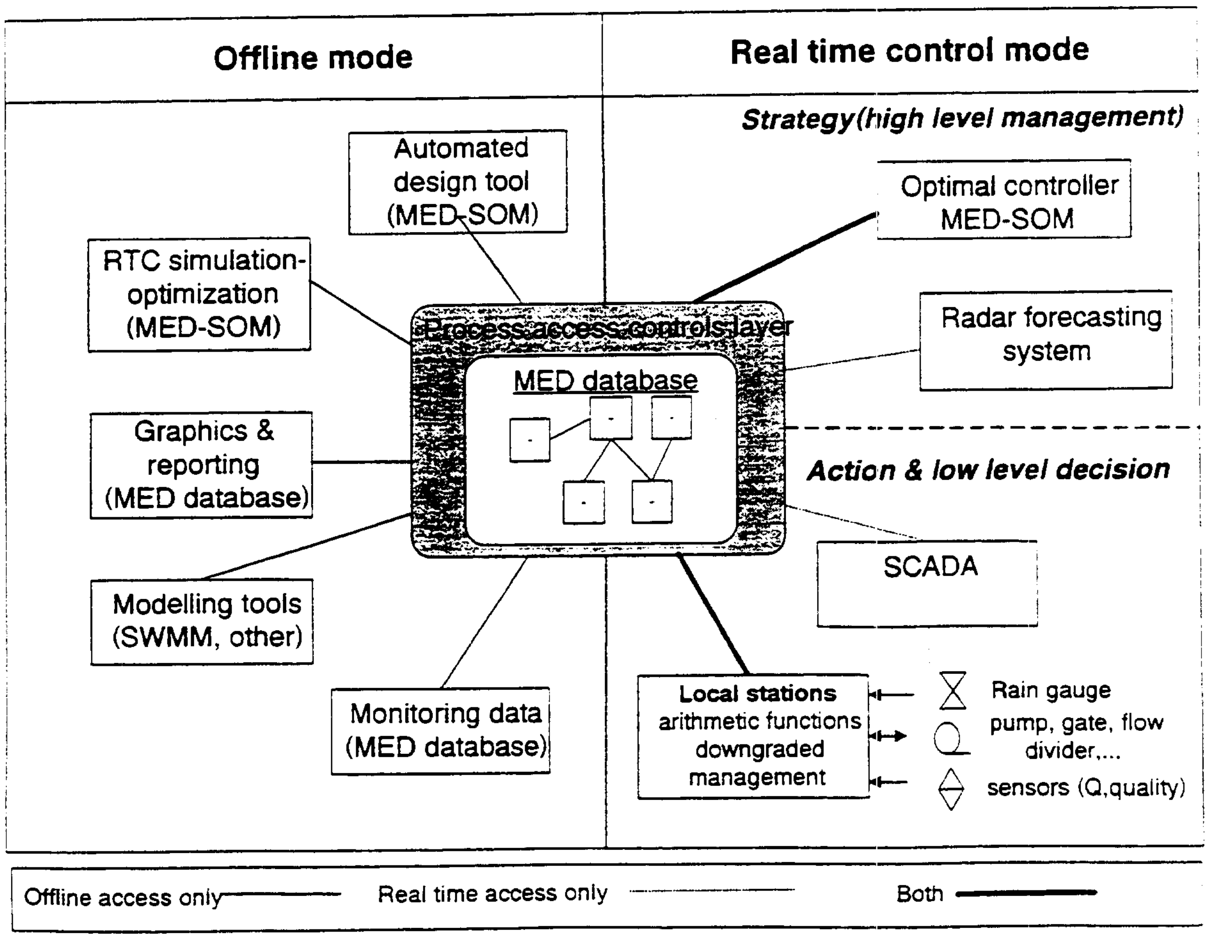
Real time control is applied to maximize the use of facilities. Because it may not be the panacea for all situations, the potential benefit of real time control must be assessed first. Long term planning also involves a complete analysis of the network to find the most feasible, reliable, and economical set of solutions that fulfills the overflow requirements. Solutions include: adding conveyance capacity to locally restrictive sections of the network; adding control gates for in-line retention; adding detention tanks with inflow and outflow control gates; modifying and/or adding capacity to wastewater treatment plants; adding online treatment at overflow sites.

Based on the behavior of the modified network. the next step consists of identifying distribution constraints imposed to the simulator-optimizer, in order to favor overflow at selected sites and eliminate overflows at other more sensitive sites. MED-SOM simulation-optimization results help demonstrate the power and the flexibility of the real time control tool since it can transfer overflows from one site to another, impose and respect constraints and manage simple optimal actions from control strategies. Furthermore, those control strategies enable managing the filling and draining of retention tanks without creating any surcharge on the interceptor network and/or at the wastewater treatment plant.

Architecture of the integrated MED system

The MED system architecture is shown in Figure 1. The MED database system serves as the central bond between various tools and processes required for off-line simulations and for on-line real-time control. Some of the dedicated processes are used in the two modes, off-line and on-line, while others are more specific. Finally, the urban drainage network model, once designed, is read from the database by the real time control system and it becomes the network to control.

Figure 1. **Functionalities of the integrated MED system throughout the design and operation process**



As it can be seen in Figure 1, there is a set of tools for each activities.

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Monitoring :

Field data can be received online from local stations and recorded into the database, and/or entered manually. The data include rainfall, water depth, flow velocities, and water quality (SS, BOD, COD, Cu, Pb, ...). These measurements can be validated by a skilled technician with the help of specialized graphical tools. Once validated, the data can be easily manipulated to produce statistics, data series at any time steps, graphics, tables, and reports. Different data series can then be superimposed to facilitate the analysis of results, and the choice of events for calibration, validation, and design. This data is then available to calibrate models. The MED Monitoring data management module can work on its own or with the complete package. It is a powerful monitoring data management tool that was designed for analysis and design purposes, not only for visualization of data.

Diagnosis :

Within the integrated system, the diagnosis of combined sewer overflows requires three sets of tools. All data input and output are handled by the MED database. This enables the user to interface with a variety of modeling and simulation software, such as SWMM, HYDROWORKS, MOUSE, CAREDAS, etc. As such, modeling tools will assist the user in defining the characteristics of the sewer network, catch basins, and other facilities. The simulation tools provide the functionality to easily define the simulation framework, identify a simulation package among those available, provide the input files to the simulator and read back the results into the database. Graphics and report tools can then be used to visualize results. The integrated system includes a built-in simulator, a real-time simulator-optimizer, MED-SOM. Parameters are then set according to the choice of simulators. Consequently, the same network can be simulated with different simulators.

Planning and testing a CSO control strategy :

As it was presented above, the dynamic simulation-optimization model, MED-SOM, is used to maximize the use of existing capacities, with or without the use of real-time control. This dynamic model is able to auto-calibrate itself on a fully non-linear hydraulic model that runs in parallel. Retention and or treatment capacities can then be added, if necessary, to attain the desired level of CSO control. The design strategy can be handled manually, by a trial and error method, or automatically processed based on a set of optimization techniques. With this automatic procedure, one has to define the physical locations, type, cost curves and performance parameters of potential facilities. An optimization routine chooses among this framework the least costly solution set that satisfies CSO control criterias. The size and location of the new facilities are then defined. This routine is coupled with the dynamic simulation-optimization model for the analysis of performance. The modified network can then be tested through simulation against various rainfall events to ensure fine tuning of the *optimal* solution set. All types of monitoring errors or other equipment failures can be simulated. The resulting performance can then be compared to see how the operating strategy will perform under downgraded situations.

Modules for the operation of a real-time control system

An integrated predictive RTC system operates the general state of the network. In order to accomplish this task, these types of systems need to be central remote control systems. The network control is distributed over three hierarchical levels. At the first control level, local stations are responsible for automatic regulation of flow regulators and the network monitoring. At the second level, the supervisory system acts as an interface between the operator and the network. It also is responsible for task scheduling and programming, and for alarms management. At the third level, the decision support system (DSS) is responsible for the optimization of flow regulation control set points Communications between level two and three is ensured by radio or modems and telephones lines. Level one and three communicate through a local area network (LAN). A radar rainfall prediction system completes the architecture of the system (figure 1). This system is also linked by a LAN to the DSS. The heart of the system is composed of a relational database management system (RDBMS) that stores all information and is the center for data exchange among level three and level two programs. The data model contains the description of all elements of the system : local stations and sensors; the sewer network and all its possible configurations; the parameter of the DSS and the control objectives. It also stores all time dependant data, such as all measurements and flow regulation set points.

Local stations :

There are as many local stations as there are data acquisition and flow control sites. Local stations are typically composed of sensors, flow regulators and data logging and communication apparatus. Local stations perform arithmetic functions during rainfall events, such as: transformation of local signals into data, local and remote communication, transformation of control set-points into field implementation, and implementing default or local flow control strategies in case of communication failures or equipment breakdowns. Also, a local data validation routine has been designed to ensure the transmission of locally validated data.

Data validation :

Data validation is crucial to real time control. In the Asseau-BPR system, data validation responsibilities is shared amongst the three levels. At the field level (level one), data validation is based on redundancy or cross validation among the sensors and flow calculation methods. It is mostly applied at critical locations for decision making. Redundant data are processed by a statistical method derived from quality control in industrial processes. Measurements are declared valid with an associated probability, giving as such a confidence level to the data. Traditional data validation techniques do not permit determination of the data validity, although the local station needs reliable data to operate local regulators under downgraded modes. Furthermore, without reliable data the DSS would receive erroneous information on downgraded states and transmit back false control set points to local stations. Both at level one and three, data is filtered by simple control techniques, such as minimum and maximum limits, measurement gradients, and the like. Level three uses these data in its retroactive loop of the control system. This retroactive loop process helps correct prediction errors of the hydraulic model included in the retroactive process (kalman filter).

Supervisory control and data acquisition (SCADA) :

Field devices grouped into local stations, are linked to a supervisory control and data acquisition system (SCADA) in order to ensure remote supervision, transmission and implementation of set-point control measures, and management of alarms. The MED system is designed to be linked to many types of supervisory software

Rainfall forecasting system :

Setting optimal flow control set points implies that it is possible to find, within a fixed time horizon, a series of instructions as a function of rainfall forecasts for the watershed. These rain forecasts can be obtained with the use of a radar system continuously calibrated with rain gauge data. The MED system was designed to work in parallel with the radar rainfall forecasting software, CALAMAR.

Optimal control system :

Essentially, this module is responsible for the simulation of the sewer network and the selection of the optimal flow control strategy in order to maximize the use of the retention and treatment capacities within the combined sewer system, including the wastewater treatment plant. Many simulation and decision support tools and techniques can be used. Although they must be robust enough to still perform satisfactorily within a noisy environment and under downgraded conditions, such as missing data and communication or other equipment failures. MED-SOM, used for the design of the CSO strategy, coupled to specific modules embedded in the database management system has the ability to operate a real time control system under such adverse conditions.

Data flow :

Monitoring data are transferred from level one to level three through different communications media Validated data are transferred directly to level three MED database. They are read by the control program which computes control set points for the entire prediction horizon. Set points are stored in the database and synchronized to current data. They are then transferred back to the local stations linked to flow regulators. Synchronization is ensured by the communication system and by the supervisor. In order to speed up data transfer for our applications, new communication protocols with error detection had to be developed.

Asseau-BPR has developed this coherent RTC approach to CSO control planning and operation over the last 5 years. The design tools have been extensively used in projects (QUC, Laval, Ile-de-France, Paris, Cleveland). Most components of the RTC system have been tested on some applications, and are presently being implemented in the city of Laval, Quebec, and in the Quebec Urban Community.

CONCLUSION

We presented some of the characteristics of real-time control projects that lead to the development of new tools and approach to real time control design and operation *Based on a large experience of CSO long term planning for a large gap of sewer networks from small ones to large complex ones using* this novel integrated RTC system, called MED, is composed of many elements that can be used for the design of CSO control plans, including different types of operational modes, such as static control, local reactive control, and global predictive real-time control. From extensive experience is CSO long term planning for a large group of sewer networks from small ones to large complex ones using this novel integrated RTC, MED was developed. It is composed of many elements that can be used for development of CSO control plans, including different types of operational modes, such as static control, local reactive control, and global predictive real-time control. Hence, the operating performances have a better chance to converge towards design performance than with systems *designed with modeling tools which can not represent real time control benefits in on a convenient way.* A central database system, MED database, acts as the central link for the design and operating components.

Among others, the most salient advantages of this integrated MED system and approach are :

- It can be adapted to any CSO control applications, whatever the advancement of the project.
- It contains all the components to design CSO control long term plans, including real time control operation
- *MED is calibrated on your preferred modeling tool leaving your staff in control of the modeling results; all optimization functions are exposed and no black box syndrom can be associated to MED*

- All components for operating real time control systems have been developed and offer the most up-to-date RTC techniques and performance. They can also be configured to many types of existing or preferred technology.
- All components are coherent with one another.
- Some of the components can be used independently, such as the monitoring data management module.
- The MED system is continuously being maintained and improved to offer the best performance.

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WET WEATHER MODELING FOR A LARGE WASTEWATER COLLECTION SYSTEM

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Fernando Gonzalez, City of Los Angeles

ABSTRACT

The City of Los Angeles has a large and complex wastewater collection system serving 3.5 million people in about 1684 square kilometers of service area. The network consists of 10,500 kilometers of sewers varying in size from 20 to 380 centimeters in diameter. Of those sewers, 1,046 kilometers are primary sewers (larger then 46 cm in diameter) discharging to the major outfall system (large sewers carrying flow to the treatment plants). Over 50 percent of the primary sewers are 50 years or older with some of them in poor structural condition due to age and corrosion. The major outfall system is about 306 kilometers long serving four treatment plants. The outfall system has pumping plants, large and complex diversion structures and an off line storage site for wet weather conditions. Besides the City, the collection system and treatment plants serve about 23 contract agencies, which are incorporated and non-incorporated areas in Los Angeles County.

This paper describes the existing wastewater collection system and the modeling of the system with hydraulic modeling software called MOUSE in both dry and wet weather seasons. The paper includes wet weather case studies where MOUSE was utilized as a tool in the decision making process.

INTRODUCTION

The City of Los Angeles has a large and complex wastewater collection system serving 3.5 million people in about 1684 square kilometers of service area that includes 25 contract agencies incorporated and non-incorporated areas in Los Angeles County. The network consists of 10,500 kilometers of sewers varying in size from 20 to 380 centimeters in diameter. Of those sewers, 1,046 kilometers are primary sewers (larger then 46 cm in diameter) discharging to the major outfall system (large sewers carrying flow to the treatment plants). The major outfall system is about 306 kilometers long serving four treatment plants.

The outfall system has pumping plants, large and complex diversion structures and an off line storage site for wet weather conditions. The complexity of the outfall network makes the task of predicting the system's behavior very difficult. Sewer management under these conditions has been based on trial-and-error and observation of past experiences. Over 50 percent of the primary sewers are 50 years or older with some of them in poor structural condition due to age and corrosion. In addition, increases in population in the service area and increasing infiltration and inflow are contributing to need of optimizing sewer flow management. Furthermore, potential natural disasters and other unpredictable phenomena increase the uncertainty about the collection system.

The Bureau of Engineering staff has developed a series of hydraulic models of multiple alternative responses in case of severe damage to the collection system or the treatment process. Moreover, to meet the planning and operation needs of the system, a dry weather dynamic flow model of the outfall system was developed using the MOUSE (Model of Urban Sewer Systems). Arc/Info GIS was used extensively to develop the model and to effectively display the results. Nevertheless, addressing wet weather issues, capacity problems, and wet weather design concerns is crucial to effectively provide valuable wastewater collection management. The modeling of such scenarios can save the Bureau of Engineering and the City of Los Angeles time and money.

This paper briefly describes the existing collection system with some of the known problems, the wet weather model development procedures, and model results obtained in solving and understanding the known problems.

METHODOLOGY

The MOUSE model was developed in two major phases, the Metro Model and the Valley Model. The Metro model is the model south of the Santa Monica mountains in the metropolitan area, and the Valley model is north of the Santa Monica mountains in the San Fernando Valley. Since most of the City's ongoing planning projects are in the metro area, this model was developed first. Figure 1 describes the various components of the model fabrication and the steps that were involved in building input files for MOUSE.

MODEL FABRICATION

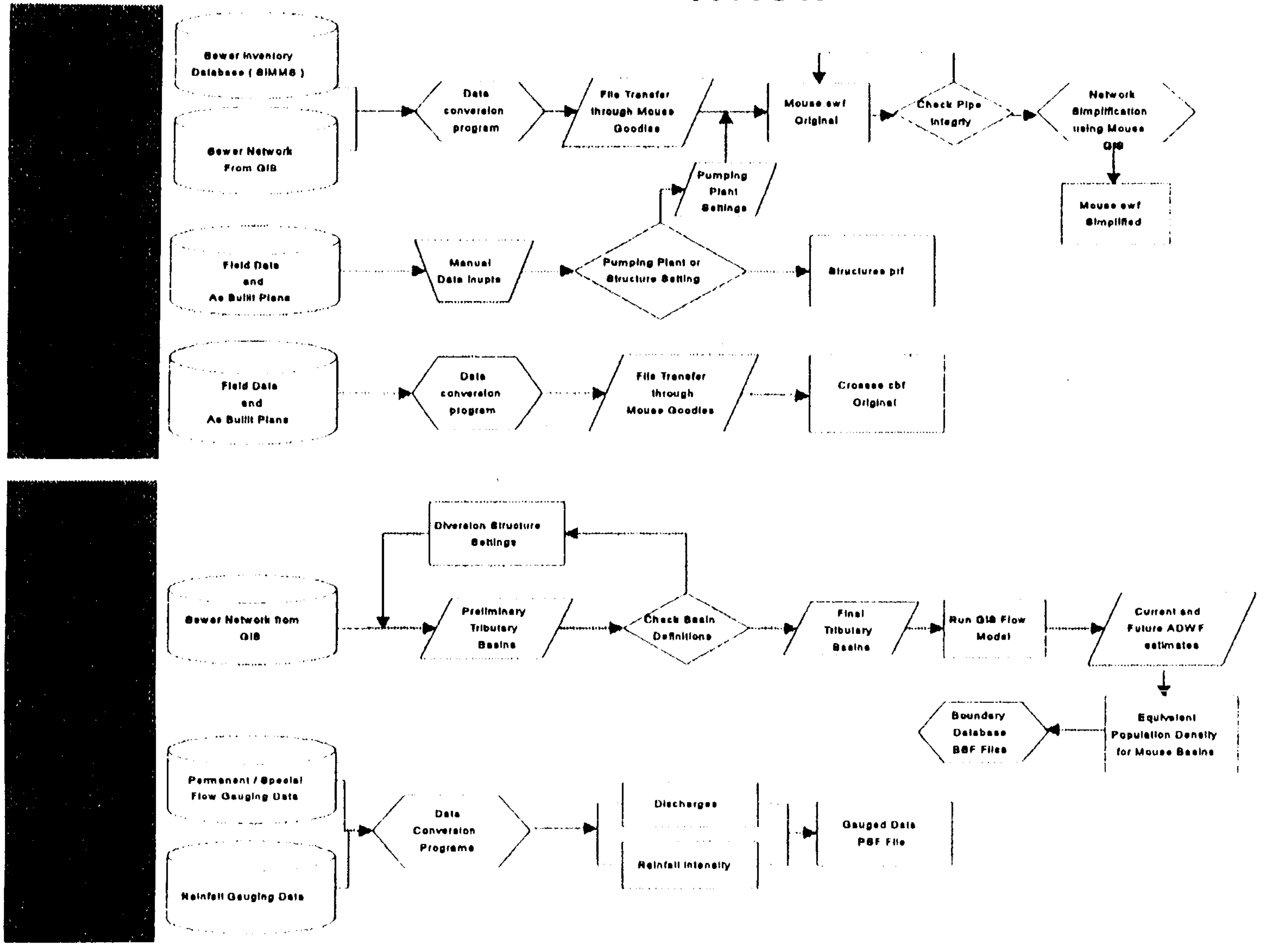

Figure 1

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The Physical Network Fabrication
The physical network fabrication process was customized by the City so that incorporating pipes, nodes, pumping plants, special control structures, and treatment plants could be accomplished efficiently. Overcoming the size and complexity of the City's sewer outfall network and the lack of readily available information regarding the sewer network, special cross-sections, treatment plants, pumping plants, and control structures was a major challenge. For effective utilization of the electronic sewer inventory data, the City developed efficient data manipulation and conversion procedures using database programs.

Dimensions of pipes, invert and top elevations, were taken from the inventory component of the City of Los Angeles Sewer Information and Maintenance Management System (SIMMS). Geographical information, such as coordinates, were taken from the GIS primary sewer network coverage. Overflow weir crests, pump wet wells and special control structures were taken from the City's *As-Built* records. Field measurements were used to verify current settings records.

The original Sewer Working File (SWF) is composed of 1,516 nodes, 2 pumping stations, 14 weir functions, and 1,561 pipes ranging in diameter from 76-cm to 381-cm for a total length of 263,195 meters. The network was checked for continuity, consistency, and missing information utilizing the MOUSE control of pipe data files and the profile drawing tool.

MOUSE GIS network editor was used for further processing and network simplification. The criteria used for simplification was: a flow direction change >30°, a slope change >0.1%, a diameter change >5%, flow capacity change >5%, or an invert elevation change >0.05 meters. The average simplification rate was 41% for pipes and 42% for nodes. The final simplified network consisted of 568 nodes and 670 pipes, 2 pumping stations, and 14 weir functions.

Through the years, as the needs for conveyance, constructability, and hydraulic efficiency have changed, different hydraulic cross-sections were designed and built into the City's sewers. In total 74 special cross-sections had to be defined and input in the database to describe the City's sewer network. These 74 shapes were variations of 4 fundamental cross-sections. They are Oval, designed in 1890, Elliptical, designed in 1905, Semi-Elliptical, designed in 1915, and Burns-McDonnell, designed in 1929. Several special programs were written to define height-to-width data for input into the model.

The pumps in the model are represented by cut-in/cut-out levels and H-Q performance curves. These data were obtained from pumping plant capacity test and technical data from the pumping plants electronically recorded flow data. Pumping plants are specified to operate at 885 L/S at 28 meters Total Design Head (TDH) and secondary operating points of 570 L/S at 35 meters TDH.

The City's outfall sewer system contains 54 major diversion structures. To simulate the operation and the correct flow split, the model includes 34 flow regulation functions and 14 weir functions. In 14 cases other diversion structures had fixed settings, and were modeled by setting the corresponding elevation in the control node. The last 14 structures required the creation of special "short pipes" to mimic special flow conditions such as underflow in special cross-section pipes.

Catchment Data
Catchment basins were defined using ArcInfo tools. Defining the sewer basins was an iterative process. First, major inlet points to the outfall system were identified using GIS. Then, using these outlets as center points, an upstream trace was performed on the sewer networks, buffers around the sewers were drawn, and polygons were generated. These polygons define the tributary area to the centers. However, from field research on flow splits and catchment areas, many basins were redefined and merged. Later, during the calibration process some sewer lines were extended for proper modeling of the network, requiring subdivision of the upstream basins. GIS provides the flexibility to redefine the affected basins with very little difficulty.

Dry-Weather Generation Model

A wastewater flow model was developed in GIS to assist the engineers in planning, analysis, and collection system management activities. The model is based on basic sanitary engineering concepts and runs on ArcInfo GIS software. The model has four major wastewater components, residential flows, employment flows, ground water infiltration, and industrial flows.

The wastewater model first defines catchment areas and overlays them with the Census coverage. This overlay process provides residential and employment population in each basin. These population numbers are then converted to wastewater flows using standard residential and employment flow generation rates. Next, the model estimates groundwater infiltration for the catchment area by overlaying the catchment basins with Infiltration/Inflow (I/I) basins. The I/I basin boundary and the infiltration rates were determined from an earlier I/I study. Finally, the model determines the industrial component from industrial discharge permit data. The summation of all these components yields the total estimated Average Dry Weather Flow (ADWF) for the tributary basins. The model generates the flows for the current year and for future years based on projected numbers. The results for the GIS based wastewater model provide the information necessary to define the catchments in the MOUSE HD model.

The MOUSE HD model defines diurnal variations of flows using the "Dry Weather Flow" option from the Boundary Data Overview. This option allows a single unit sewage flow rate and a single diurnal variation to generate sanitary curves for each tributary basin. A statistical analysis of calibrated historical data from 33 ultrasonic flow monitors defined the diurnal wastewater flow variation. Further processing of the results from the ArcInfo flow model were required to calculate equivalent catchment data. An equivalent population density was defined for each catchment basin. This number was obtained by dividing the total 24-hour flow generation by the unit wastewater flow rate. Catchments whose area was bigger than 1,000 hectares were adjusted by proportionally increasing the equivalent population density.

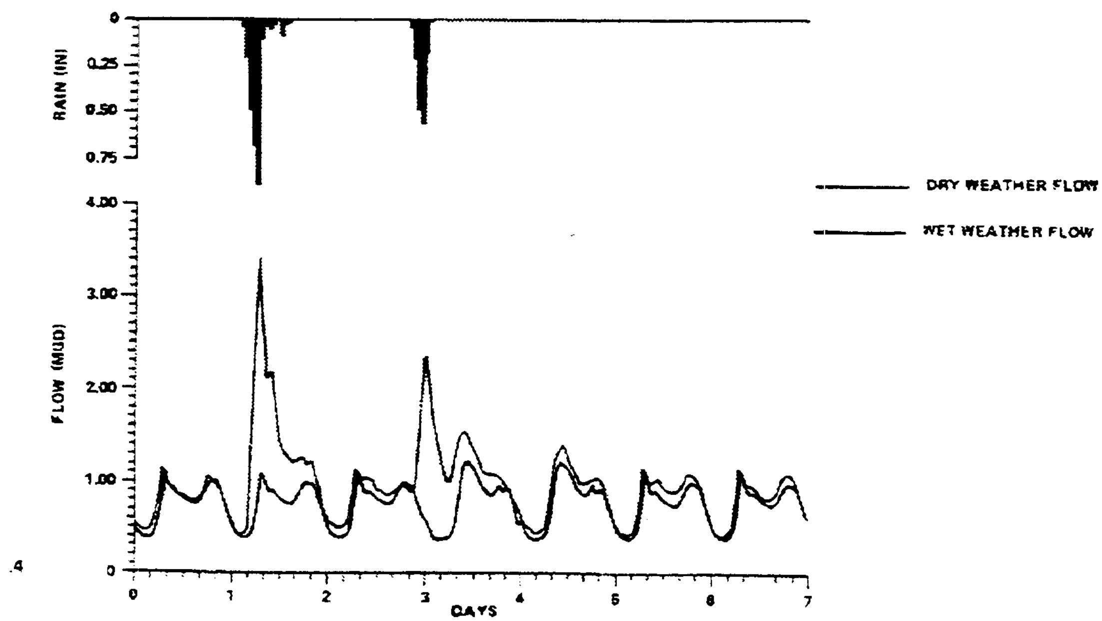

Figure 2

Wet Weather Generation Model

As part of a system wide I/I reduction study, rainfall data was collected from eighteen continuously recording rainfall recording stations. The results of the analysis indicated that Rainfall Dependent Infiltration/Inflow (RDI/I) can equal or exceed peak dry weather flow rates; groundwater and surface flow from storms contribute to infiltration; inflow comes almost exclusively from storm water. Studies of the Infiltration/Inflow in the Los Angeles

R0025302

watershed determined that approximately 10 to 20 percent of the total RDI/I is inflow and 80 to 90 percent is infiltration. Figure 2 shows a typical normal dry weather base flow and wet weather flow hydrograph.

The volume of storm water entering the sanitary sewer system is related to the age and condition of pipes and maintenance holes, and the number of direct connections from illegal lawn and roof drains. These are combined into a runoff factor "R," which is expressed as a percentage of the total volume of rainfall that could potentially enter the sewage collection system. Values for all 206 drainage basins previously identified were developed using a geographic analysis by using isohyets contours, sewer age data, maintenance records, and information from the I/I study for the City of Los Angeles.

The wet weather inflow hydrographs were generated using MOUSE Surface Runoff Models. From the choices available, Surface Runoff model "A" with level of catchment description 1 was chosen because no detail description of the catchment area is used. Rain water is reduced for a value of the initial loss plus a lumped hydrological reduction. The actual hydrological losses and the runoff process itself are left out of the computation. The total catchment surface which contributes to runoff as impervious area is determined by the "R" factor previously defined.

Model Verification

To calibrate a large model takes a long time and it is very difficult to maintain the overview with a model of this complexity. Therefore, the approach taken was to verify the ability of the hydraulic model and flow generation model to replicate the observed behavior of the actual system on both dry weather scenarios and wet weather scenarios for 9 sub-models.

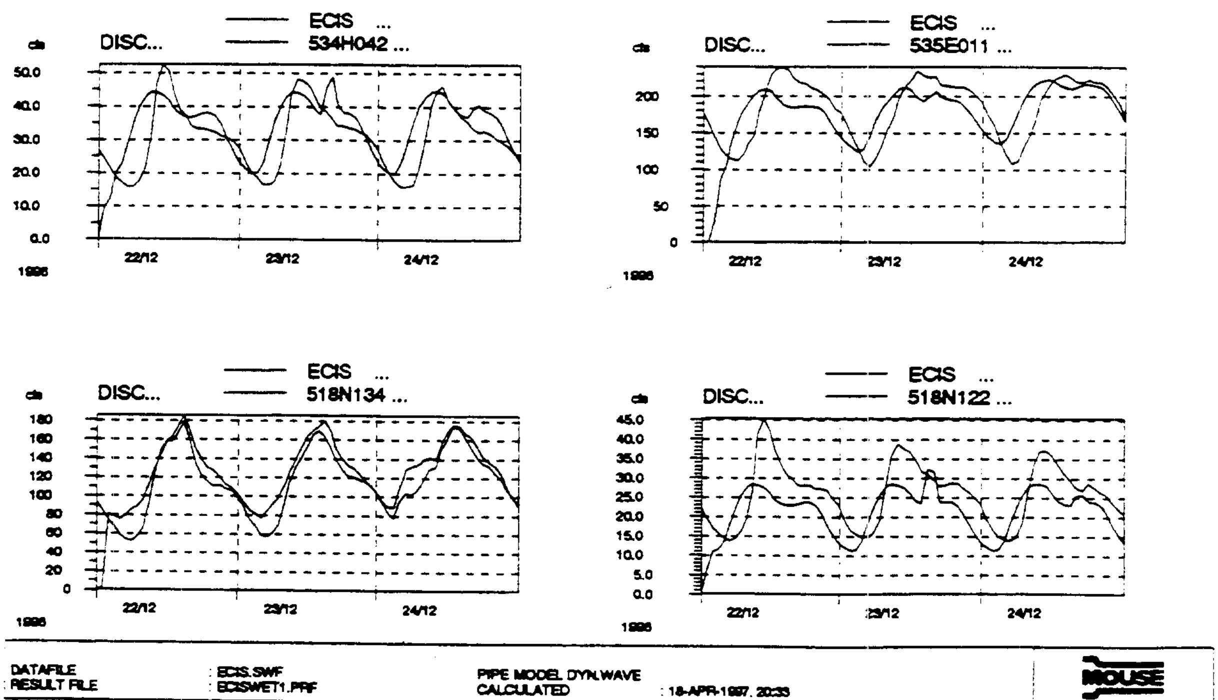

Figure 3

Dry Weather Behavior

The Manning's *n* friction factor and the predicted nodal inflow were calibrated to match the actual dry weather flow levels. Friction factors were changed to accommodate for silt and debris deposits, especially in older pipes, as well as other unknown phenomena. Such *n* values were within a much larger range than those specified in text books based on pipe material only. The modeled flows and levels were then compared to gauged flow rates and levels from 33 permanent ADS ultrasonic flow monitoring stations. The goodness-of-fit standard was set at 80 percent of absolute variation.

Wet Weather Behavior

The rainfall event selected for wet weather calibration was a gauged front loaded 2-year return frequency event. This storm event was gauged between December 22-24, 1996 at the City's rainfall monitoring stations, and was the biggest storm event during the 1996-1997 rain season. The rain data was processed by the MOUSE Runoff Model "A" to generate flows for input directly to MOUSE HD.

The routed flow rates and levels from the model were compared with the gauged flow rates and levels recorded at 32 permanent ultrasonic ADS flow monitoring stations. The goodness-of-fit standard was set at 80 percent of absolute variation. Figure 3 shows the calibration results of the same 4 major outfalls described above.

Case Studies

The wet weather preparedness and operation planning group of the Bureau of Sanitation defined eight (8) different emergency scenarios and conditions to be studied for the 1997-98 rainy season in Southern California. Peak wet weather flow conditions were run for each scenario defined. The peak wet weather was based on the synthetic 10-year back-loaded intensity-duration-frequency (IDF) curve.

Rain Event

Based on recommendations in Technical Memorandum 6B of the Advanced Planning Report, the 10-year return frequency back-loaded synthetic IDF storm was selected for analysis. Results from these runs provided the baseline level of preparedness in the event of heavy rainfall. It provided a high (90 percent) level of preparedness against system overflows and conveyed all but one of the historic storms that occurred over the past 40 years of record. The one exception was a 100-year storm in the San Fernando Valley in February 1980.

Nevertheless, the 10-year IDF storm is conservative. It assumes the unlikely event of uniform storm intensities and durations from the 10-year event throughout the city. The February 1980 event is an example of variances in the storm pattern. This storm approached the 100-year return frequency in the northern parts of Los Angeles, but it was bellow the 10-year return frequency in the downtown and West Los Angeles areas.

The Intensity-Duration-Frequency (IDF) method allows direct comparison of the effects of differing storm return frequencies while eliminating the storm duration and intensity variables. An IDF storm has a synthetic, variable intensity hyetograph, which contains the rainfall intensity for the desired storm return frequency for all durations. For the 10-year return storm the peak hour intensity and volume are the intensity and volume associated with the 1-hour intensity and volume for a 10-year storm.

Simulation Results

To better understand the dynamic simulation results, the wastewater collection system was divided into 27 different segments. Each segment defined a portion of a major outfall sewer network. A profile was then defined for each segment and the Hydraulic Grade Line (HGL) studied carefully. Surcharge and potential spills were identified throughout the network. Other areas of interest considered are the pumping plants, the treatment plants, and selected diversion structures. Under this scenario, the two upstream treatment plants are on-line. No collapses are considered in the simulation and diversion structures are set to their "normal" operating position. A summary of findings from the dynamic simulation can be seen in Figure 4.

Potential Spills

Sewer spills are represented as circles in Figure 4 and described in the following list.

AVORS	Along Burbank Blvd between Sepulveda and Tyrone
EVRS	Upstream of the Tujunga Wash Siphon
LCSFVRS	Upstream of the WHIS junction
NOS	Along Mission Rd between Glendale Blvd and Eagle Rock Blvd
NOS	Upstream of 41st and VanNess

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COLLECTION SYSTEMS ENGINEERING DIVISION
HYDRAULIC MODEL SIMULATION RESULTS

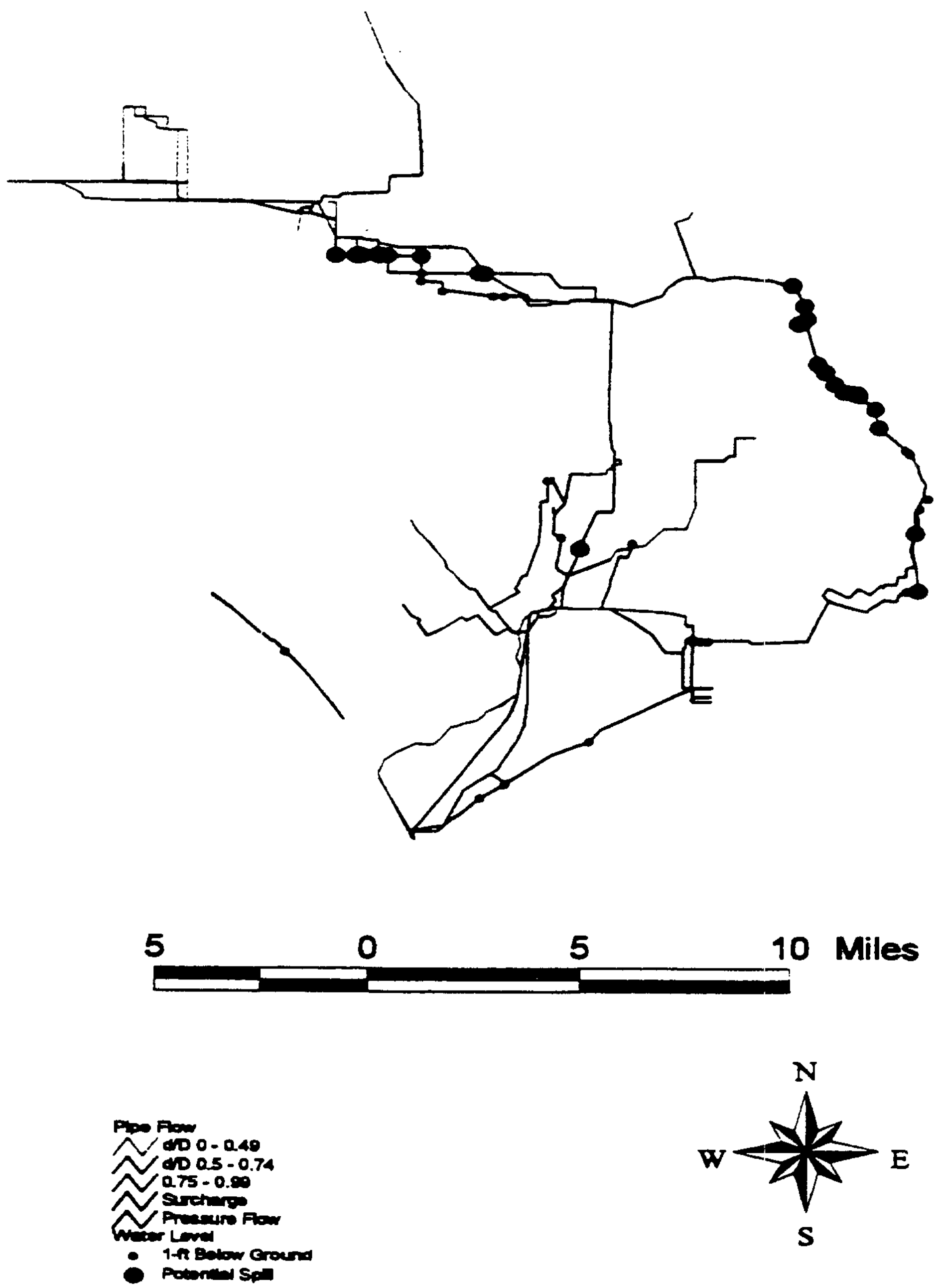

Figure 4

Sewer Line Surcharges
The following lines present potential surcharge conditions:

VORS	Along Acama between the Hollywood Fwy and Forman Ave
NOS	Along Magnolia between Kester and Woodman
NOS	Along LA River between Universal and Griffith Park
NOS	Upstream of the LA River siphon at Ventura Fwy
NOS	Upstream of the LAG inlet
NOS	between Glendale Blvd and the 23rd St junction
NOS	Upstream of the 41st and Van Ness Diversion
SB MAZE	Along Vernon, Crenshaw, and MLK
COS	Between LAX and Imperial Ave
LCIS	Upstream of NORS diversion structure #2

A typical sewer profile with the hydraulic grade line can be seen in Figure 5. A longitudinal profile of the sewer line along Mission Rd. between Glendale Blvd. and Glendale Blvd. and Eagle Rock Blvd. is displayed. The hatched area represents the space between the pipe and the ground surface. Maintenance holes are labeled along the alignment. The water surface, represented as pressure line, has been plotted. Surcharge conditions, along the entire line, are identified where the water level line is higher than the pipe soffit. Spill conditions, at nodes 468K029, 468K046, and 468P001, are represented where the water line is higher than the ground elevation.

Concluding Remarks
For a large collection system with limited staff resources, the response to an overtaxed system during rainfall events can be critical. The use of wet weather simulation gives engineering staff the necessary tools to plan for contingencies and allocate staff during actual storm events. The hot spots in the City are highlighted so the response can be coordinated with the various maintenance yards and on-call staff can be shifted to the necessary areas.

Many challenges were encountered in the development of the Model of the City of Los Angeles Outfall Sewer System. The model network fabrication was a major task because of the size and complexity of the collection system. However, effective data transfers, using existing electronic databases and GIS tools, were the keys to overcoming this challenge. The results have confirmed the validity of using fully hydrodynamic models for the simulation of large urban sewage networks. The model has successfully simulated flows within the City's large and complex system that includes many pipe interconnections, pumping plants, large catchment basins, special hydraulic structures, and reverse flow conditions. With the successful development of the model, MOUSE will become an integral part of the planning and design activities for the City's wastewater facilities.

The City's primary planning strategy will incorporate GIS and MOUSE linked together in a comprehensive scheme which allows increasing sophistication in the modeling procedures. The MOUSE model will be integrated into overall wastewater management from planning and design flows to operational procedures, and can accommodate both a system-wide approach or localized special studies. With GIS, continuous gauging programs, and sophisticated dynamic model calibration can be continuously refined, and models will play an increasing role in optimizing the life of facilities, thus saving City's precious dollars and infrastructure investment.

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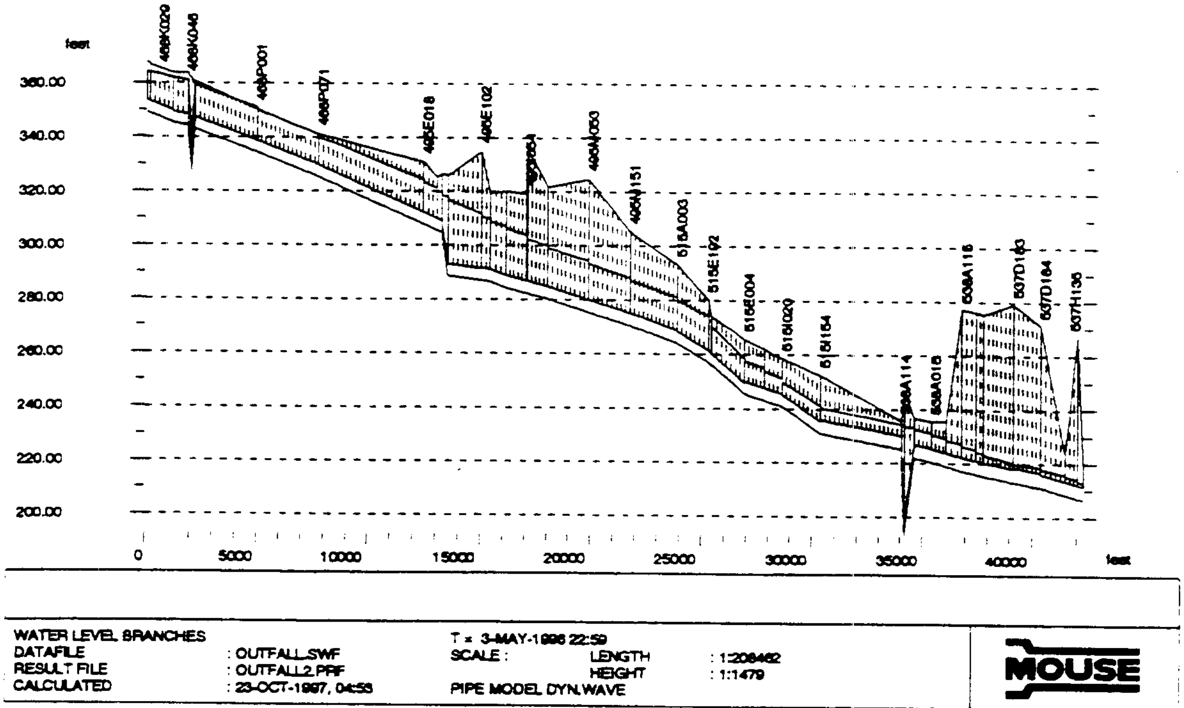

Figure 5 PROFILE No. 13

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ILE-DE-FRANCE CENTRAL REGION DRY AND WET WEATHER WASTEWATER STUDY USING A WATERSHED APPROACH

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ABSTRACT

The central zone of the Ile-de-France Region includes some 8 million inhabitants, nearly 200 municipalities, 4 Departments, including the city of Paris, and parts of 4 other Departments, covering an area of 1900 km^2 (750 sq.mi.).

The study's goal is to design a plan that enables to meet, in the year 2015, the dry and wet weather water quality objectives of the Seine and the Marne Rivers. Hence, the study includes all sources of water pollution: urban and industrial wastewater, dry weather overflows, CSOs, SSOs, and stormwater.

In order to obtain a streamlined approach, a watershed approach was retained taking into consideration all sources of pollution and ensuring to meet the water body quality objectives. The approach consisted in defining the maximum load capacity of receiving water bodies, during dry weather and various rainfall events. Four very distinct scenarios were developed.

Comparison of the four scenarios is based on their environmental performance, the nuisance created by the construction and operation of the facilities in these densely urbanized and sometimes historic areas, and their operating and construction costs. We used a multi-criteria analysis to sort out the best scheme and developed its implementation schedule according to the financial capabilities.

KEYWORDS

Watershed analysis, CSO Control plan, Wastewater, Treatment, Stormwater, River analysis.

INTRODUCTION

The central zone of the Ile-de-France Region, namely the Greater Paris agglomeration, includes some 8 million inhabitants, nearly 200 municipalities, 4 Departments and parts of 4 others, and covers an area of 1900 km^2 (750 sq.mi.). In this territory, two levels of government, municipalities and Departments, and the Paris Agglomeration Wastewater Commission (SIAAP) are directly involved in the management of wastewater and stormwater networks. The French Government, the Ile-de-France Region, and the Seine-Normandie Water Agency all help finance the construction of waterworks. The SIAAP is more specifically responsible for the interception of wastewater and its treatment.

In 1992, the SIAAP prepared a wastewater management long-term plan. The plan relied on highly centralized wastewater treatment solutions, which received a strong opposition from the public. It also proposed the construction of very large infrastructures for the control of CSOs. In 1995, the French Minister of Environment requested the preparation of a wastewater study, which would take into consideration diverging views on the orientation of the wastewater treatment scheme. The goal of the study was to meet, within a time span of the year 2015, the dry and wet weather water quality objectives of the Seine River and the Marne River, along with requirements from Northern Sea Water Quality Treaty. Hence, the study included all sources of water pollution: urban and industrial wastewater, dry weather overflows, CSOs, SSOs, and stormwater.

In March 1996, Asseau-BPR, in collaboration with two other French engineering firms, was commisioned to conduct the study of the central area of the Ile-de-France Region dry and wet weather wastewater management plan under a watershed approach.

Approach

Asseau-BPR devised a watershed approach taking into consideration all sources of pollution and ensuring the satisfaction of the water quality objectives.

First, it consisted in defining the maximum load that the receiving water bodies could assimilate, during dry weather and during various rainfall events.

Having fixed these maximum allowable loads that can meet water quality criteria, it was possible to design scenarios that reduced loads accordingly. Four scenarios were designed. They reflected to various degrees the views of the proponents of more centralized and more decentralized wastewater treatment system. All four scenarios were equivalent in meeting dry and wet weather water quality criteria.

Comparison of the four scenarios is based on their environmental performance, the nuisance created by the construction and operation of the facilities in these densely urbanized, and sometimes historic areas, and their operating and construction costs. A multi-criteria analysis was used to sort out the best scheme and develop its implementation schedule, and the cost.

Review of the existing situation

Given that they are located in a densely populated area where combined sewer systems are predominant, the Seine and the Marne are highly utilized by sewer overflows, particularly during rainfall events. In fact, there are nearly 240 stormwater outfalls in the Seine and the Marne (SSO,CSO, stormwater outfalls). Moreover, some municipal and industrial sectors are still not connected to the sanitation network and the wastewater is poured without treatment into those rivers, during wet or dry weather. All that results in a water quality deficiency on the Seine and Marne, which restrains the use of the area and impact on aquatic life.

The wastewater treatment system is served by 4 main treatment plants : the downstream Seine plant (Achères, 2 100 000 m^3/d), the upstream Seine plant (Valenton, 300 000 m^3/d), the downstream Marne plant (Noisy, 18 000 m^3/d) and the Bonneuil plant (50 000 m^3/d). Another station is presently under construction, the center Seine de Colombes with a planned capacity of 240 000 m^3/d.

In addition to these plants are three pre-treatment plants ensuring the effluent grit and sand removal (the Clichy plant, the Briche basin, and the Ile Martinet pump station). These plants' effluent flows through the great SIAAP interceptor, which is one of the 5 interceptors that flows to Achères WWTP.

The network's average flow during dry weather is evaluated at nearly 2.8 Mm^3/d, and will reach nearly 2.9 Mm^3/d in year the 2015. In addition to the wastewater (sanitary and industrial) representing nearly 61% of total supply, this volume includes a significant quantity of infiltration and inflow.

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Although the water quality of the Seine and the Marne is average good to passable during dry weather, in accordance with the water quality objectives, the situation is quite different during rainfall events. Take for instance the rainfall events of the summers of 1994 and 1995, which caused significant water quality deterioration and a considerable quantity of fish kills.

The Marne has high ammonia content in dry weather, greater than 0.5 mg/l, due to upstream overflows. The Seine deteriorates along its course and its quality is strongly affected downstream of the main treatment plant's effluent discharge (Achères). The contents of dissolved oxygen reaches 2 mg/l downstream of Achères, while the concentration in BOD_5 becomes superior to 10 mg/l and the concentration of NH_4^+ is greater than 2 mg/l all along the Seine downstream of this same treatment plant. During rainfall historical events (July 1994 and July 1995) the dissolved oxygen content of the Seine fell to 0 mg/l after violent rainstorms, occurring several dozens of kilometers downstream of Paris. Moreover, we have observed considerable fish kills following violent rainstorm events.

Water quality criteria

The receiving water body's quality objectives are the local priority. France's agreements in regards with the Northern Sea Treaty quality criteria are:

- 5 mg/l of dissolved oxygen during dry weather, and 4 mg/l for 24 hour duration, 2 mg/l for 6 hour duration, and 1 mg/l in any time duration during wet weather;
- 0.5 mg/l of ammonia, 50 mg/l of nitrate, 11 mg/l of total nitrogen, and 0.5 mg/l of phosphate at any time.

Evaluation of required interventions

We first assembled all information to forecast dry weather sewage production and wet weather generation in the year 2015, and assessed the sewer system and wastewater treatment plant conditions and efficiency. We developed a hydrologic and hydraulic water and sewershed model, to assess wet weather flows, CSOs, and stormwater flows. The models were calibrated against data from large historic rainfall events (July 1994 and July 1995). Thus, overflow hydrographs of each CSO site have been obtained. These hydrographs are associated to overflow pollutograms used for receiving water quality impact modeling.

Representative overflow pollutographs of different collectors and interceptors of Paris and its suburbs were built from a water quality wet weather database. These representative pollutograhs are separated in a maximum of 15 water quality classes. These classes are associated to the overflow sites, which the network's characteristics (watershed and planned water quality behavior) are the nearest to the measures sites definition used to generate them. The overflow hydrographs are analyzed and separated in phases of rise and drop of water level to allow the association of the different quality classes. These pollutographs have easily been built, thanks to the use of the MED software, developed by Asseau-BPR.

Dry weather

A first level of intervention has been applied on all scenarios:
- Correction of connections/junctions in sectors non-attached to the network;
- Reduction of infiltration and inflow by 300 000 m^3/d;
- For all WWTP, addition of nitrification and phosphorous removal facilities.

Wet weather – Evaluation of volumes and pollution loads to control

From a first evaluation of volumes and pollution capacities, poured into the receiving water body during historical events and reference homogeneous rainfall, it has appeared that a small number of important overflows represented more than 80 % of the organic mass overflow during rainfall events. Therefore, it was chosen to prioritize the efforts in controlling pollution in these overflow sites. It has been shown that the control of 80 % of organic loading overflows, for a 6-month return period rainfall, enabled the achievement of water quality objectives. Thus, it has been chosen to completely control the overflows on the main CSO sites (42 out of 240 sites) for bi-annual rainfall. The choice of a 6 month return period to size CSO control facilities is backed up by the possible load control obtained for small return period rainfall events: 60 % for 1 year rainfall, 48 % for 2 year rainfall, 38 % for 5 year rainfall and 29 % for 10 year rainfall.

Intervention scenarios

To allow the control of these wastewater volumes, and to meet the receiving water body quality criteria, 4 intervention scenarios were developed. Each of the four scenarios (see table 1) were designed for structural improvements, including combinations of best management practices (in-line/off line retention, centralized/satellite high rate treatment, water transfers from one basin to another, etc) and for evaluating the potential of implementing global integrated predictive real time control. For this, we used a software we developed in-house (MED-SOM).

The scenarios apply for both dry and wet weather. They reflected to various degrees the views of the proponents of more centralized and more decentralized wastewater treatment systems. All four scenarios were equivalent in meeting dry and wet weather water quality criteria.

Table 1. **Summary of the main infrastructures proposed for CSO control during rainfall events**

Scenario A	*Scenario B*	*Scenario C*	*Scenario D*
16 detention tanks **892 000 m^3**	**16 detention tanks** **878 000 m^3**	**15 detention tanks** **847 000 m^3**	**14 detention tanks** **840 000 m^3**
3 detention tunnels **(19.6 km; 751 000 m^3)**	**2 detention tunnels** **(10.1 km; 543 000 m^3)**	**4 detention tunnels** **(20.6 km; 801 000 m^3)**	**4 detention tunnels** **(16.6 km; 675 000 m^3)**
1 high rate treatment plant **(2.5 m^3/s)**	**7 high rate treatment plant** **(8.5 m^3/s)**	**1 high rate treatment plant** **(2.5 m^3/s)**	**1 high rate treatment plant** **(2.5 m^3/s)**
7 WWTP **Capacity** **Dry w. : 34 m^3/s** **Wet w. : 107 m^3/s**	**7 WWTP** **Capacity** **Dry w. : 33 m^3/s** **Wet w. : 105 m^3/s**	**9 WWTP** **Capacity** **Dry w. : 34 m^3/s** **Wet w. : 96 m^3/s**	**9 WWTP** **Capacity** **Dry w. : 34 m^3/s** **Wet w. : 105 m^3/s**

To these infrastructures are added, for all scenarios, the connection of all non-connected sectors to the sanitation network, the separation of some areas and the doubling of certain collectors. Note that the existing wastewater treatment plants are included in the compilation.

Thus, the scenarios are analyzed and compared between them, in order to determine strengths and weaknesses and to identify the best scenario. For this analysis, 3 rainfall events are used: homogeneous rainfall of 6 month and 10 year return periods and the 2nd July 1995 historical rainfall event.

Hydraulic analysis of scenarios - Dynamic management

When trying to maximize wastewater treatment and flow interception, dynamic flow control represents an additional solution to all the proposed interventions. The influence of dynamic flow control of the great SIAAP interceptors, compared to a static flow regulation, has therefore been evaluated. This analysis has been made from the MED-SOM model, developed by Asseau-BPR, allowing the simulation and optimization of the wastewater treatment system management.

The four intervention scenarios were the objects of a MED-SOM modeling for two reference homogeneous rainfalls (6 month and 10 year return period), and the July 2nd 1995 historical rainfall event. The simulations have also been done in the static management mode with help of the CAREDAS model. The comparison of the results allows seeing the advantages of the dynamic management.

Table 2 compares, for each scenario, the overflow results in accordance with the management mode applied. Alone the networks' downstream zone of the Ile-de-France Region's central zone is included in this evaluation, which corresponds to about half of the studied zone's whole overflow.

Table 2. **Results of the downstream section of the zone of study**

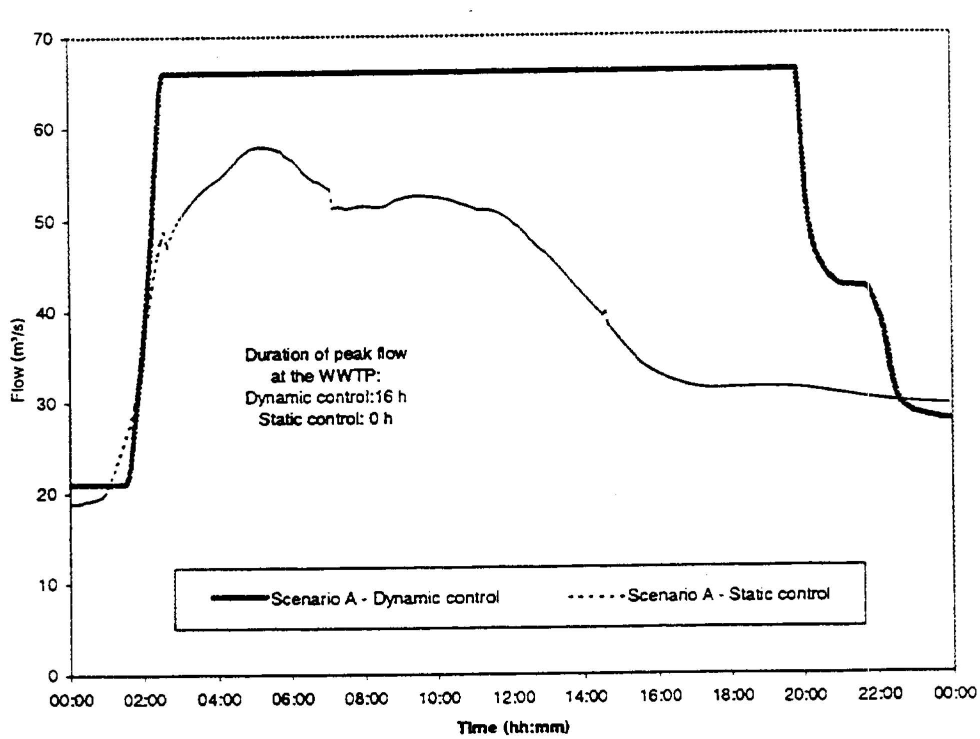
Rain	Scenario	Overflow volume (Mm^3)		
		Static	Dynamic	Situation
				1 826
1/6 months	A	46	0	
	B	67	0	
	C	0	0	
	D	0	0	
				4 596
1/10 years	A	2 207	1 787	
	B	2 316	2 247	
	C	2 240	1 694	
	D	2 081	1 332	
				4 195
02-July-95	A	1 400	1 016	
	B	1 932	1 403	
	C	1 831	1 367	
	D	1 846	1 332	

So it appears that for the 6 month rain period, the scenarios allow a 100 % elimination of overflows (a little less for the static). For the 10 years rain, the dynamic management allows in average, a 62 % reduction of overflowed volumes whereas the gain obtained with the static management is 52 %. However, the dynamic control influence is greater in a real rainfall event dynamic management allows for a 70 %

reduction in overflows for the 2nd July 1995 rainfall event, while the reduction with the static management mode is 58 %.

The performance comparison, in the situation of either a real time or static control, shows that it is very interesting to integrate, within each scenario, certain advanced solution possibilities calling for real time control. In the situation of the actual rainfall event of the 2nd July 1995, the real time control actually allows performance 30 % to 25 % better than a scenario considering only static control. This increased performance is obtained by the optimal use of WWT plants capacity during an important period, as shown on graphics comparing the flows at the Achères' wastewater treatment plant in static or real time control for the 2nd July rainfall event for scenario A (diagram 1). Thus, static control allows full capacity use of the station during 16 hours for this event.

Figure 1. **Scenario A – Inflow to Achères WWTP for the 2nd July 1995 rainfall event.**



Receiving water body impacts (environmental performances of scenarios)

The receiving water body quality impact evaluation is performed with the PROSE model, developed by CERGRENE in the context of the Piren-Seine project. This model evaluates the variation in water quality of the Seine and the Marne. The pollution associated to the hydrographs simulated to each SSO is included as data for the PROSE model.

Dry weather

The simulation results demonstrate that the developed dry weather scenarios allow for the improvement of the receiving water body quality. The dissolved oxygen, the NH_4 and the PO_4 are the parameters showing the most noticeable gains. The downstream sites are the most favorably influenced by the proposed facilities.

- DO: all scenarios allow, the reach of quality criteria.
- NH_4: strong improvement but objectives are not achieved everywhere because of high ammonia concentration upstream in the Marne River.
- NO_3: respect the quality target everywhere, however a significant rise downstream of Achères due to the high level of nitrogen load in the effluent.
- PO_4: the four scenarios cause a significant concentration reduction compared to the reference situation, without however conforming to prescribed criteria.

Wet weather

In average for the 4 scenarios, the planned interventions allow to reduce organic loads in receiving water body by 80 % for the 6-month rainfall, 45 % for the 10 years rainfall and 65 % for the 2nd July 1995 rainfall event.

Table 3. **Evaluation of the overflow reduction for different scenarios.**

		Overflow reduction percentage compared to the reference situation				
Rain	**Scenario**	**Volume**	**SS**	**BOD**	**COD**	**NH4**
6 months	A	55.3	70.5	79.9	72.8	63
	B	54.8	70.0	80.1	730	63
	C	54.5	69.7	79.8	72.7	63
	D	54.5	69.7	79.8	72.7	63
10 years	A	28.0	40.2	45.8	38.4	31.6
	B	25.7	39.0	43.8	36.9	25.2
	C	27.5	39.6	46.1	38.6	30.6
	D	29.2	41.9	48.6	41.4	28.5
2 July 95	A	42.5	54.6	67.0	59.0	46.3
	B	39.1	52.8	64.7	55.6	36.6
	C	38.6	51.8	64.4	55.6	42.1
	D	38.9	52.2	65.1	55.7	38.4

Wet weather impact on water quality was simulated with the PROSE software, developed by the École des Mines de Paris School, respecting the following summer conditions:

- The overflows generated by 6 month and 10 year return period rainfall, and the 2nd July 1995 rainfall event, on low reference conditions, of once in 5 year return period;

- The overflows generated by the 2nd July 1995 rainfall event on low water conditions prevailing on the 2nd July 1995.

The pollutant load reduction results in the Seine's and the Marne's sharp water quality improvement. The quality objectives are reached for the 6-month return period rainfall event and the 2nd July 1995 historical event. However, a 10 year return period homogeneous rainfall and the 2nd July 1995 rainfall event, associated with a low flow situation (5 years return frequency), always leads to anoxic conditions. Moreover, we have demonstrated that the conjunction of low frequency rainfall and severe low water flow was very unlikely. For example, these past 18 years, there was only one important event combining low water conditions and rain susceptible to cause more critical effects than the 2nd July 1995 historical event.

The scenarios' multi-criteria analysis

The four scenarios A, B, C and D represent contrasting development alternatives. The proposed developments allow the achievement of the receiving water body quality objectives during dry weather. During wet weather, the differences between the scenarios are more pronounced, particularly in nitrogen polluted inflows.

The costs and nuisances associated to each scenario are also contrasted and depend on many factors, more or less favorable to one or another of the scenarios.

To classify the scenarios and to single out the most effective one, it is necessary to proceed to a multi-objective analysis, allowing the classification of the scenarios by relative performance according to different criteria. The criteria considered in this analysis are: environmental performance, progressive implementation capacity, operating nuisances, implementation constraints, construction nuisances, operation costs, and investment costs. These analysis criteria are only technical and we give them a score between of 2 to 5 relative to each other.

For each studied criteria mentioned earlier we have obtained a classification. The final results are shown in table 4.

Table 4. **Multi-table analysis of the four intervention scenarios**

	Before balancing				**Balancing**	**After balancing**			
Analysis criteria	**A**	**B**	**C**	**D**		**A**	**B**	**C**	**D**
Environmental performance	3	2	5	4	25 %	0.75	0.5	1.25	1
Functioning flexibility	2	3	4	5	15 %	0.3	0.45	0.6	0.75
Progressive implementation	5	4	3	2	10 %	0.5	0.4	0.3	0.2
Exploitation nuisances	4	2	5	3	15 %	0.6	0.3	0.75	0.45
Implementing constraints	5	3	4	2	10 %	0.5	0.3	0.4	0.2
Construction nuisances	5	4	3	2	5 %	0.25	0.2	0.15	0.1
Exploitation costs	5	3	4	2	10 %	0.5	0.3	0.4	0.2
Investment costs	5	4	3	2	10 %	0.5	0.4	0.3	0.2
Total (X/5)						**3.9**	**2.85**	**4.15**	**3.1**
Total (%)						**78**	**57**	**83**	**62**

Resulting from this multi-objective analysis, scenario C appears to be the most efficient of all four scenarios.

CONCLUSION

The sewer system of the central zone of the Ile-de-France Region services a population of 8 million inhabitants over a territory of approximately 1900 km^2. In its present state, water quality of the Seine and Marne Rivers is severely impaired by effluents from existing WWTP, SSOs, CSOs, and stormwater, during dry and wet weather.

Asseau-BPR has been mandated to conduct a planning study to meet dry and wet weather water quality criteria in a horizon of the year 2015. A watershed approach was performed, where water quality in the two main rivers draining these watersheds became the main design criterion, both for dry and wet weather. We present here the main result of this study, which was finalized in a time of 1.5 years.

Four scenarios were developed. They include the construction of some 1.4 Mm^3 to more than 1.6 Mm^3 of new retention capacity and 2.5 m^3/s to 8.5 m^3/s of high rate treatment plant capacity. The existing 5 wastewater treatment plants are to be upgraded to include more wet weather capacity and nitrogen and phosphorous removal. Depending on the level of wastewater treatment decentralization, two more treatment plants are also included.

All of these four scenarios help meet water quality criteria during dry weather and wet weather, for events such as the historical rainfall event of July 2nd 1995, which has a return period of 5 to 10 years.

USE OF THE WATERSHED MANAGEMENT APPROACH TO REDUCE THE IMPACT OF COMBINED SEWER OVERFLOWS AND TO ADDRESS STORM WATER PHASE II "DONUT HOLES"

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ABSTRACT

The City and County of San Francisco operates and maintains the City's combined sewer system and wastewater treatment plants. The combined system collects and stores for treatment, both sanitary and industrial wastewater, as well as storm water runoff. To meet stricter effluent limits for discharge to San Francisco Bay and the Pacific Ocean, the City's Bureau of Environmental Regulation and Management (BERM) operates the Water Pollution Prevention Program (WPPP)—which is targeting categories of discharges, such as industrial, commercial, and residential, to reduce their loading of heavy metals and other pollutants of concern to the City's system and ultimately the Bay and Ocean. The City recently completed a 20-year, $1.4 billion dollar Master Plan for Wastewater Management that significantly reduced the number of combined sewer overflows (CSOs) that occur during wet weather. The goal of the new Storm Water Pollution Prevention Program (Storm Water Program) is to reduce the potential impact of the few remaining overflows by minimizing the amount of pollutants that enter the combined sewer system from outside sources during wet weather.

The City implemented the Storm Water Program as a pilot effort in one drainage basin (i.e., watershed) starting in 1995 to test its efficacy and appropriateness for the City as a whole. The WPPP chose to focus the program on a watershed of concern to the City and its efforts to: 1) protect its citizens and the environment, and 2) remain in compliance with environmental regulations. As a result, the Storm Water Program was implemented in the Lower Army and Lower Selby sub-basins of the Islais Creek watershed. The combined size of these two sub-basins was small enough to allow for the implementation of a comprehensive storm water pollution prevention program while being large enough to represent a significant effort in the watershed. The Lower Army and Lower Selby sub-basins are the closest sub-basins in the watershed to Islais Creek, and are a representative sample of the whole watershed's land uses including industrial, commercial, residential, and transportation.

The Water Pollution Prevention Program used a watershed management approach, and linked the Storm Water Program to: 1) the requirements of its NPDES permits, 2) USEPA's Combined Sewer Overflow Control Policy, and 3) upcoming Phase II requirements. San Francisco's combined sewer system presented an interesting opportunity to use the watershed management approach, which is associated more with nonpoint source pollution, in a "point source" situation. San Francisco's well defined major basins, sub-basins, and drainage districts facilitated the use of data on wet weather hydrology and the combined sewer system's hydraulics to understand flows and drainage patterns, and their impact on CSOs. Integrating traditional storm water management techniques and the watershed management approach into the City's existing water quality control programs not only helped it to reduce the potential impacts of combined sewer overflows, but will also facilitate San Francisco's efforts to comply with Phase II storm water regulations well ahead of schedule.

INTRODUCTION

The City and County of San Francisco operates and maintains the City's combined sewer system and wastewater treatment plants. The combined system collects and stores for treatment, both sanitary and industrial wastewater, as well as storm water runoff. To meet stricter effluent limits for discharge to San Francisco Bay and the Pacific Ocean, the City's Bureau of Environmental Regulation and Management (BERM) operates the Water Pollution Prevention Program (WPPP)—which is targeting categories of discharges, such as industrial, commercial, and residential, to reduce their loading of heavy metals and other pollutants of concern to the City's system and ultimately the Bay and Ocean. The City recently completed a 20-year, $1.4 billion dollar Master Plan for Wastewater Management that significantly reduced the number of combined sewer overflows (CSOs) that occur during wet weather. The goal of the new Storm Water Pollution Prevention Program (Storm Water Program) is to reduce the potential impact of these few remaining overflows by minimizing the amount of pollutants that enter the combined sewer system from outside sources during wet weather. The City implemented the Storm Water Program as a pilot effort in one drainage basin (i.e., watershed) starting in 1995 to test its efficacy and appropriateness for the City as a whole.

METHODOLOGY

Framework

The City developed a Program Plan that describes the framework for the pilot Storm Water Program. The Program Plan is a living document designed to grow in length and detail as the Storm Water Program evolves and becomes more defined. The first phase of the pilot program was designed to identify, scope out, and develop the elements of a comprehensive, long-term watershed management effort. The first phase work set the stage for further program implementation in subsequent phases. The City chose to use information on watershed management planning provided in the "(g) Guidance" (USEPA, 1993) to develop the framework for their pilot Storm Water Program. The "(g) Guidance" includes a table (Table 4-11. Watershed Management: A Step-by-Step Guide) adapted from Livingston and McCarron (1992) that describes the general steps for developing a watershed management plan. The steps include:

- conducting inventories and creating maps of watershed characteristics,
- identification of pollutant sources,
- identification of expected changes in land use and infrastructure,
- setting resource management goals and pollutant reduction targets,
- selecting management practices, and
- developing the watershed management plan.

The City adapted these steps to their situation in developing the Program Plan.

Program Approach

San Francisco used this watershed management approach, and linked the Storm Water Program to: 1) the requirements in the City's NPDES permits, 2) USEPA's Combined Sewer Overflow Control Policy, and 3) efforts of other Bay Area storm water programs. The watershed management approach is being used more and more in storm water programs to create effective and efficient urban runoff management programs. This approach attempts to ensure that the right things are done, in the right places, at the right times. San Francisco's combined sewer system presents an interesting opportunity to use the watershed management approach, which is associated more with nonpoint source pollution, in a "point source" situation. San Francisco's well defined major basins, sub-basins, and drainage districts facilitated the use of data on wet weather hydrology and the combined sewer system's hydraulics to understand flows and drainage patterns, and their impact on CSOs. The following steps were used in developing and conducting the Storm Water Program.

1. Characterize watershed and identify problems - As a result of previous work, BERM staff had identified heavy metals (particularly copper and mercury), PAHs, PCBs, dioxin, and selected pesticides as the pollutants of concern for San Francisco. However, it was important to review and verify this list on a regular basis. Of this list, some pollutants are more likely than others to be "storm water" pollutants, that is pollutants that enter the combined sewer system via runoff. In addition, the list of problem pollutants can change because of stricter regulations or permit limits, changing treatment capabilities, or new monitoring information.

In addition to identifying the problem pollutants, Water Pollution Prevention Program staff decided to focus the program on a watershed of concern to the City and its efforts to protect its citizens and the environment, and to remain in compliance with environmental regulations. As a result, the Storm Water Program was implemented in the Lower Army and Lower Selby sub-basins of the Islais Creek Watershed.

This watershed is in the southeast portion of the City and drains to San Francisco Bay. It is expected that the combined size of these two sub-basins is small enough to allow for the implementation of a comprehensive storm water pollution prevention program while being large enough to represent a significant effort in the watershed. The Lower Army and Lower Selby sub-basins include the Potrero Hill and Bernal Heights sections of the City, represent the closest sub-basins in the watershed to Islais Creek, and appear to be a representative sample of the whole watershed's land uses including industrial, commercial, residential, and transportation. To implement this part of the approach, the following tasks were undertaken:

- Delineate and map on a geographic information system (GIS) the sub-watershed boundary and sub-basin boundaries.

- Inventory and map on GIS the storm water conveyance, storage, and treatment system including streets, catch basins, open channels, pipes, pump stations, Southeast Wastewater Pollution Control Plant, storage structures, outfalls, and overflow structures. Provide information on size, storage capacity, treatment capacity of the system, and frequency, volume, and duration of overflows. Note the parts of the system, if any, that are not connected to the Southeast Plant.

- Identify and map to the extent possible ongoing and planned infrastructure improvements, their size, storage and/or treatment capacity, and the date they are expected to be operational.

- Inventory and map current land use by sub-basin. Define and map by at least major categories, such as commercial and residential, and consider defining and mapping sub-categories such as single family residential and multi-family.

- Identify and map zoned land use by sub-basin using the same categories and level of detail as used for current land use inventory and mapping.

- Identify and map to the extent possible ongoing and planned significant developments or redevelopments by land use.

- Inventory and map impervious area (e.g., streets, sidewalks, and roofs) and significant areas of open space or bare soil. To the extent possible, note impervious area that is directly connected to the storm water conveyance system.

2. Identify significant storm water sources with the highest potential of influencing the quality of the City's combined sewer overflows - Based on studies conducted by the City and other agencies, there is relatively complete information on the sources of storm water pollutants. However, new information is always being generated and the sources can change because of changing processes, practices, or products. Therefore, it is important to track this information by reviewing literature and networking with staff from other agencies. It is also important to a watershed management effort to identify and involve stakeholders including residents, businesses, and community groups. As a result, the City recognized that this step could be a major one, so the City focused on developing a framework and the tools first, that could be used later to expand or revise the Storm Water Program, as necessary. To implement this part of the approach, the following tasks were undertaken:

- Review the list of storm water pollutants of concern and identify the most likely sources by land use category or sub-category (e.g., category = residential or sub-category = single family). Generate a list of these land use categories and sub-categories. *

- Identify and record contact information on the major stakeholders in the watershed including large businesses, trade associations for business types that have a significant presence in the watershed, large municipal and other government facilities, City departments with responsibilities that may impact/protect storm water quality, commercial business districts, community groups, and neighborhood associations. Use existing data bases such as the City's business tax license, and in-house lists of trade associations, business district contacts, and community and neighborhood groups.

- Gather and review the City's information on wet weather hydrology and the combined sewer system's hydraulics and operations to understand flows and drainage patterns, and their impact on CSOs. Note the climatic/hydraulic conditions, if any, when combined flows do not go to the Southeast Plant but rather to overflow structures. *

- Based on this review, and the information gathered previously on the storm water conveyance system, identify geographic areas that could be significant sources of pollutants to storm water runoff and discharges through combined sewer overflows. *

- For businesses, review USEPA's list of industries subject to the Phase I storm water regulations and confirm or modify the categorization based on the specific information for the Islais Creek watershed. *

* These tasks will result in a list of potentially significant sources of storm water pollutants of concern. Sources will be on this list because:
  - the land use category or sub-category has been identified as a potentially significant source of storm water pollutants by studies conducted by the City or others, or

  - the geographic area is a potentially significant source because of the design and operation of the storm water conveyance system, or

  - the business type has been identified as a potentially significant source of storm water pollutants by studies or permit programs (e.g., State Industrial General Permit).

The relative contribution of problem pollutants can be estimated by using source and monitoring data. Although these calculations often have large margins of error because of incomplete or inconsistent data, it is still important to go through the exercise, especially when new data becomes available, to confirm the relative importance of the sources. It is also important when focusing on sources to compare their contribution with other sources (e.g., commercial vs. residential) to keep the programs focused on the most significant problems. To implement this part of the approach, the following tasks were undertaken:

- Review studies and reports conducted by the City or others to determine the priority of these potential sources for each of the storm water pollutants of concern. These studies and reports included:
  - for businesses - source identification and outreach programs in the City and elsewhere, inspection and permitting information from the Department of Public Health and BERM, commercial/industrial watershed-based efforts in other jurisdictions, and the USEPA Multi-Sector Permit (1995);

  - for residential - source identification studies and outreach programs in the City and elsewhere;

  - for transportation - reports and studies from the Federal Highway Administration, Caltrans, storm water programs, and others.

3. Identify practical storm water pollution prevention strategies that would reduce the amount of pollutants entering the City's combined sewer system - The strategy for dealing with storm water pollutants is fairly generic but the mix of program elements can change depending on factors such as, land uses, relative contribution of problem pollutants, number and size of businesses in the watershed and their general awareness of environmental regulations. Program strategies may include ordinance revisions, modified discharge permits to include storm water criteria, inspections, monitoring, interdepartmental coordination, workshops, on-site visits, outreach materials, advisory committees, feedback mechanisms, and incentives. The City decided to develop a watershed management approach for dealing with all the major storm water pollutant dischargers in the watershed that is based on the success of their current programs and incorporates the appropriate program elements. To implement this part of the approach, the following task were undertaken:

- Using the prioritization of sources by storm water pollutant of concern, a strategy was developed for each pollutant. The strategies vary depending on the predominant source(s).

- For residential sources, the strategy focuses on outreach including potentially: mailings, speakers bureau for neighborhood meetings, displays at community events, and citizen's advisory committee(s).

- For businesses, the strategy starts with outreach as well, including potentially: establishment of advisory committees, workshops, on-site visits, distribution of outreach materials (such as a general storm water pollution prevention guide), and follow-up. The strategy also includes permitting via the City's Class II permit including a qualifying checklist and storm water pollution prevention plan provisions.

- For transportation sources, there are two categories—public (roads, bridges, and parking) and private (driveways and parking).
  1. For the public transportation areas, the strategy differs based on which agency (City or State) has jurisdiction. As it has in the past, BERM will work with other City departments to develop and implement a strategy for "City streets." The strategy includes enhanced street cleaning, catch basin cleanouts, and special programs for bridges and parking lots. For State-owned transportation areas, the City is working with Caltrans' ongoing storm water pollution prevention program.

  2. Significant sources on private parking areas and driveways are dealt with through either the business or residential elements.

4. Develop storm water technical outreach materials to be distributed to targeted storm water sources - Like the strategies for dealing with storm water pollutants, the best management practices (BMPs) are also fairly generic. Technical outreach materials (e.g., general storm water education booklets, specific BMPs, checklists) have been developed for the vast majority of polluting activities and target audiences. BERM has developed many of these materials and used these existing materials to develop new materials for San Francisco. This approach allows BERM to concentrate on verifying, modifying, and fine tuning existing information for San Francisco and a combined sewer system. To implement this part of the approach, the following tasks were undertaken:

- Develop a generic outreach piece suitable for multiple audiences that explains the overall Storm Water Program—its goals, approach, elements, roles of different stakeholders in the watershed, and City contact information.

- Develop a generic storm water pollution prevention outreach piece suitable for businesses. Develop a companion storm water pollution prevention checklist for distribution to business sources that are not likely to be getting more specific outreach and/or permitting information.

- For specific sources, review existing City as well as other agency outreach materials for appropriateness to the Storm Water Pollution Prevention Program. Modify existing or develop new outreach materials for specific sources. The specific technical outreach materials will likely include: general information on storm water pollution, source-specific information on storm water pollutants and pollution prevention practices, and checklists to be used either in self-audits or for on-site visits by the City.

- For the permitting portion of the business strategy, review the existing Class II permit provisions for storm water for appropriateness for specific business types. Modify existing or develop supplemental provisions, as necessary, to ensure the effectiveness of the permit in preventing storm water pollution. Use the State's Industrial Storm Water BMP Handbook (SWQTF, 1993), Industrial General Permit (State of California, 1992), and USEPA Multi-Sector Permit as guidance to activities of concern and BMPs.

5. **Develop a GIS data base containing the targeted storm water sources** - Water Pollution Prevention Program staff used the existing GIS data base work at BERM and integrated it with the GIS efforts elsewhere in the City. The GIS data base assisted in tracking storm water pollutant sources and facility audits, as well as in program implementation and evaluation. Use of GIS is integral to watershed and storm water management and the City's early work with GIS greatly facilitated implementation of the Storm Water Program.

6. **Conduct educational storm water pollution prevention audits** - For business and government facilities, having determined the pollutants of concern, their sources, the area of focus (i.e., parts of the sub-basin(s)), and the pollution prevention strategy, tools, and BMPs; the City conducted pollution prevention audits or other educational outreach to the target sources. To implement this part of the approach, the following tasks were undertaken:

- Conduct pollution prevention audits including an identification of storm water sources, determination of their significance, and assessment of BMP or pollution prevention practice implementation. Use checklists and outreach materials developed under previous tasks to facilitate the audits and educate the facility owner/operator. Non-storm water discharges entering the storm water conveyance system will be reduced using pollution prevention practices. Non-storm water discharges entering receiving waters directly will be eliminated as soon as possible after discovery.

- Provide feedback to owners/operators at the end of visits and through periodic mailings.

- Develop a follow-up strategy based on threat to water quality, implementation of pollution prevention practices, and when appropriate, compliance with permit conditions.

7. **Evaluate the effectiveness of the storm water pollution prevention program** - To evaluate the program's long term success, ways of measuring results must be incorporated into the program design. The sooner that the types of data necessary to measure success are identified and data collection started, the quicker the feedback and the sooner corrections can be made to increase the program's effectiveness. The City developed an evaluation methodology as an integral part of the Program Plan for the Storm Water Program.

RESULTS

To illustrate implementation of the City and County of San Francisco's pilot Storm Water Program we will focus our discussion of results on the pollution prevention audits conducted as part of the business strategy. Audits including identifying sources of storm water pollution, determining the significance of these sources, and assessing the use of best management practices were conducted of selected businesses. The choice of businesses was based on a compilation of databases including Standard Industrial Classification (SIC) Codes identified in the Phase I storm water regulations, the City's pretreatment database, and the City's hazardous materials program database.

The compilation effort produced a list of 172 businesses located in the project drainage area. The business locations were fixed on the City's geographic information system and maps were produced. A drive-by survey was conducted to verify the businesses' locations. During the drive-by survey, businesses that were found but not listed were added to the audit list, and those businesses that were not found but listed were excluded. The final candidate audit list consisted of 145 business facilities.

A checklist of potential outside activities (e.g., vehicle maintenance, outside storage) was prepared and the businesses were audited. For businesses with storm water exposure, comprehensive audits were performed including site sketches and comments. For those that had no activity or storage exposed to storm water, only facility information was recorded. Audit information was entered in an Access database directly from the checklists. The audit results can be summarized as follows:

1. Among the 145 businesses audited, 45 (31%) of them had an activity or storage exposed to storm water, and 100 (69%) had no exposure.

2. The most common activities at businesses with storm water exposure are:
   - Outdoor loading/unloading — 40% of facilities
   - Outdoor storage — 36%
   - Vehicle/equipment washing — 33%
   - Vehicle/equipment fueling — 31%
   - Vehicle/equipment maintenance — 31%
   - Outdoor process equipment — 7%

3. Among the 45 businesses with exposure to storm water, only five had outdoor process equipment. The possibility of storm water pollution from outdoor processing may be relatively low.

4. Some potential outside activities such as building/grounds maintenance, building repair/construction, and over-water activities were found to be unlikely sources of storm water pollution in the project drainage basins because no businesses were found conducting these activities.

5. The incidence of storm water pollution in the project drainage area is more likely linked to the improper handling of leaks and spills, and inadequate protection for vehicle/equipment service and outdoor unloading/loading areas.

6. Dry weather flows were found at 21 facilities, which constitutes 47% of the businesses exposed to storm water or 14% of businesses audited. The majority of the dry weather flow was from washing/cleaning.

7. None of the on-site storm drains were labeled and few were inspected by facility staff. Some drains were clogged with debris or were heavily contaminated by oil/grease.

8. Of all businesses in the drainage area, the most common Standard Industrial Classification codes in the drainage basin are: Group 75 (automotive repair, services, and parking) (11%), Groups 50 and 51 (whole sale trade) (10% and 8% respectively), Group 27 (printing, publishing, and allied industries) (8%), Group 17 (construction) (7%), Group 41 (local and suburban transit) (7%), Group 52 (building materials, hardware, garden supply) (7%), and Group 73 (business services) (7%).

9. A review of the number of facilities with exposure to storm water runoff out of the total number of facilities in the drainage area shows that certain SIC codes appear more likely to have activities exposed to storm water runoff (see Table 1). The likely SIC codes include: Group 43 (United States Postal Services) (100%), Group 41 (local and suburban transit) (83%), Group 55 (auto dealers and gas stations) (71%), Group 52 (building materials, hardware, garden supply) (42%), Group 75 (automotive repair, services, and parking) (37%), Group 17 (construction) (27%), and Group 73 (business services) (27%).

10. The data showing which facilities are more likely to have activities exposed to storm water runoff can be extrapolated to the rest of the City to determine the magnitude of expanding this pilot effort City-wide.

Table 1. List of Standard Industrial Classification Codes with Likely Exposure to Storm Water Runoff

SIC Group	Description	Number of Facilities*	Percentage
43	United States Postal Services	1 / 1	100
41	Local and suburban transit and interurban highway passenger transportation	10 / 12	83
55	Automotive dealers and gasoline service stations	5 / 7	71
87	Engineering, accounting, research, management, and related services	1 / 2	50
52	Building materials, hardware, garden supply, and mobile home dealer	5 / 12	42
75	Automotive repair, services, and parking	7 / 19	37
17	Construction-special trade contractors	3 / 11	27
73	Business services	3 / 11	27
20	Food and kindred products	1 / 4	25
42	Motor freight transportation and warehousing	1 / 4	25
76	Miscellaneous repair services	1 / 4	25
51	Whole sale trade-non-durable goods	3 / 14	21
50	Whole sale trade-durable goods	3 / 17	18

* Based on number of facilities with exposure to storm water runoff out of total number of facilities in drainage area of same SIC code.

DISCUSSION

The development and implementation of a pilot Storm Water Program in one portion of the City starting in 1995 will greatly facilitate San Francisco's response to the coming Phase II regulations.

Phase I - Although San Francisco's total population is high enough for the City to be subject to the 1990 Phase I federal storm water regulations (i.e., > 100,000), the regulations allow a municipality with both separate and combined sewers to petition USEPA to reduce its listed population to account for storm water discharged to combined sewers and treated in a POTW. The reduction method is based on the proportional length of each sewer type. Since the vast majority of San Francisco is served by combined sewers, the length of separate sewers is insufficient to trigger the Phase I regulations.

Phase II - The approach in USEPA's proposed rule (1998) is that all municipal separate storm sewer systems within a Census-designated urbanized area (e.g., San Francisco) would be regulated under Phase II, regardless of whether or not a particular municipality had combined sewer portions of its system. This approach would require the City to meet storm water regulations in the "storm water" portions of the city (the so-called "donut holes") and the nine minimum CSO controls in the combined sewer sections. San Francisco's proactiveness and Phase II's long timelines (final rule - 3/1/99, applications due 3 years, 90 days later = 5/31/02) mean that these regulations will act more as a "backstop" than as a "driver" to the City's Storm Water Program.

Certain industrial activities (identified by SIC code), including construction sites of 5 acres or more, are covered by State of California's General Storm Water Permits. San Francisco's existing Water Pollution Prevention Program and pilot Storm Water Program are very consistent with the Phase I and II requirements.

Table 2. Comparison of Storm Water Management Program Elements

Element	Phase I	Phase II	General Permits	San Francisco
Program Management	X	X		X
New (Re-) Development/Construction	X	X	X	X
Illicit Discharges	X	X		X
Industrial/Commercial	X		X	X
Public Agencies	X	X		X
Public Education	X	X		X
Program Evaluation/ Monitoring	X	X		X

The permitting process for San Francisco will likely be similar to other Storm Water Management Programs (SWMPs) where a plan is developed and submitted with an application. It is expected that the NPDES permit language will be mostly boilerplate and refer to the plan which can be updated without affecting the permit language.

Since the City currently holds three NPDES permits (one each for its two POTWs and one for Bayside CSOs), the City and the Regional Water Quality Control Board (Regional Board) will explore the possibility of merging requirements into one or two permits. However, this effort may be constrained by the differing legal statutes behind the requirements (i.e., CSO, storm water). In addition, the Regional Board is starting to consider developing a General Permit for municipal storm water. The City and Regional Board will decide at the time of the application which permitting approach to use (e.g., General Permit, individual permit, "merged" permit).

Since San Francisco is served by both combined sewers and separate sewers, the application will clearly indicate which geographic areas of the City are served by separated systems including the Port of San Francisco, parts of Golden Gate Park, and presumably new portions of Bayside that are being redeveloped—China Basin, Mission Bay, Candlestick Point, Hunter's Point, Treasure Island). Because the industrial storm water regulations are written to hold the "owner/operator" responsible, the City's application will also include information on how the City has decided to handle private industrial/commercial facilities on City property served by separated systems.

The City will use several guides in developing its permit application including USEPA and State guidance, as well as the current plans of neighboring Storm Water Management Programs (e.g., Alameda, San Mateo). The application will cover the following elements of SWMPs, which are consistent with both Phase I and II requirements, as well as the elements of the City's pilot Storm Water Program.

- Program Management
- New (Re-) Development/Construction
- Illicit Discharges
- Industrial/Commercial
- Public Agencies
- Public Education
- Program Evaluation/ Monitoring

CONCLUSIONS

Integrating traditional storm water management techniques and the watershed management approach into the City's existing water quality control programs not only helped it to reduce the potential impacts of combined sewer overflows, but will also facilitate San Francisco's efforts to comply with Phase II storm water regulations well ahead of schedule.

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DEVELOPMENT OF THE MWRA LONG-TERM CSO CONTROL PLAN USING THE DEMONSTRATION APPROACH

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ABSTRACT

In July, 1997, the Massachusetts Water Resources Authority (MWRA) completed facilities planning for controlling combined sewer overflows (CSOs) in the greater Boston area in accordance with a federal court schedule. The CSO control plan was developed using the demonstration approach described in the national CSO policy issued by the U.S. Environmental Protection Agency (EPA) in April, 1994. Under the demonstration approach, MWRA confirmed through the facilities planning process that the recommended plan complied with water quality standards. Both technology-based and water quality-based evaluations were performed. The MWRA CSO control plan was developed using the demonstration approach because sufficient data on CSO and non-CSO sources of pollution and corresponding water quality impacts were available and were considered in determining appropriate controls on a site-specific basis. This paper presents the process followed to document compliance with the criteria for a successful demonstration under the EPA CSO control policy.

KEY WORDS

technology-based evaluations, cost/performance, water quality standards, hours of violation, project optimization

INTRODUCTION

EPA, following extensive input from numerous state, municipal, and environmental stakeholder organizations, published its new national CSO Control Policy in April, 1994. The policy implements a national strategy to achieve cost-effective CSO controls that meet appropriate health and environmental objectives. It provides for flexibility in developing long-term CSO control plans and allows CSO controls to be tailored to address site-specific impacts of CSOs. The policy requires that nine minimum control technologies be implemented and establishes a planning process for developing long-term CSO control plans by evaluating a range of CSO control alternatives and demonstrating compliance with water quality standards to protect designated uses.

According to EPA's CSO policy, plans for long-term CSO control and compliance with water quality-based requirements of the Clean Water Act can be developed by using either a "presumption" or "demonstration" approach. Under the ***presumption approach,*** compliance with water quality standards is presumed, if one of three performance criteria is met: i) overflows are reduced to no more than an average of four events per year on an annual average basis, ii) no less than 85 percent by volume of the combined sewerage collected on a system-wide annual average basis is eliminated or captured for treatment, or iii) no less than the mass of pollutants causing water quality impairment for the volume reductions in number ii is eliminated or reduced.

Under the ***demonstration approach,*** compliance with water quality standards is confirmed through the CSO control planning process. This approach was intended to provide flexibility in developing a long-term CSO control plan, particularly where water quality standards are not met due to non-CSO sources of pollution. While not necessarily satisfying the performance criteria of the presumption approach, the plan can be shown to be adequate to meet water quality standards. The demonstration approach depends on a detailed assessment of receiving waters and the impacts of CSO discharges and other sources of wet weather pollutants on water quality.

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Under the definition of a successful demonstration, a long-term control plan must meet the following criteria:

i The planned control program is adequate to meet water quality standards and protect designated uses, unless standards or uses cannot be met as a result of natural background conditions or pollution sources other than CSOs;

ii The CSO discharges remaining after implementation of the planned control program will not preclude the attainment of water quality standards or designated uses, or contribute to their impairment. Where standards and uses are not met in part because of natural background conditions or pollution sources other than CSOs, a total maximum daily load (TMDL) allocation should be used to apportion pollutant loads, including a waste load allocation and a load allocation or other means;

iii The planned control program will provide the maximum pollution reduction benefits reasonably attainable; and

iv The planned control program is designed to allow cost effective expansion or cost effective retrofitting if additional controls are subsequently determined to be necessary to meet water quality standards or designated uses.

MWRA developed its CSO control plan using the demonstration approach because detailed information on CSO and non-CSO sources of pollutant loads and resulting water quality impacts was collected and could be evaluated in determining appropriate controls based on site-specific conditions. The MWRA successfully demonstrated that its recommended CSO control plan fulfilled each one of the required criteria.

METHODOLOGY

Because CSOs are considered to be point sources of pollution, both technology-based and water quality-based requirements of the Clean Water Act apply in their control to meet water quality standards and protect designated uses. The development of the MWRA's CSO control plan included evaluation of a full range of CSO control technologies, as well as detailed water quality assessments of CSO impacts on specific receiving water segments. MWRA's approach followed the planning requirements of EPA's CSO policy, confirming compliance with state water quality standards.

MWRA's long-term control plan recommends CSO controls for Boston, Cambridge, Somerville, and Chelsea. CSOs from the large sewerage system serving these communities impact Boston Harbor and its major tributaries, including the Charles River. Due to the size and complexity of the system, as well as the diversity of the affected waterbodies, the plan was organized to address 14 distinct receiving water segments.

Technology-Based Evaluations

Technology evaluations were conducted for each outfall and/or group of hydraulically-related outfalls. The alternatives evaluation process involved several screening steps to ensure that detailed evaluations were only performed for feasible alternatives. One method for comparing alternative technologies involved cost/performance curves. Cost/performance curves were developed based on annual model simulations. Two sets of curves were developed, with percent reductions based on CSO load reductions and on total load (CSO plus non-CSO pollutant load) reduction in the impacted receiving water. Curves generated for individual project alternatives showed cost versus CSO load removed as a percent of baseline CSO load, and curves for the receiving waters showed cost versus total load removed as a percent of baseline total load. Parameters analyzed included fecal coliform bacteria, total suspended solids (TSS), and biochemical oxygen demand (BOD) pollutant loads from CSO, stormwater, and upstream or boundary sources, if applicable. This approach was effective in assessing the relative benefit of varying levels of CSO control on the receiving water in terms of all pollutant sources.

Feasible alternatives were also compared using a rating and ranking methodology to identify a preferred alternative on a receiving-water-wide basis. Each alternative was assigned ratings for specific criteria under the categories of water quality impacts, cost, and siting. The ratings under each category were summed and a rank order was established. The rank orders of all the categories were then summed to obtain an overall rank order for the alternatives.

Water Quality-Based Evaluations

EPA's demonstration approach also requires that the recommended CSO control plan be proven adequate to comply with water quality standards by demonstrating that each of four criteria is met. Receiving water quality models were developed and applied to compare the performance of varying levels of CSO control to baseline conditions in the receiving waters. Comparisons were facilitated using pollutant isopleths for a 2-dimensional model of Boston Harbor, and using pollutant concentration profiles for 1-dimensional models of the Charles River and Mystic River. Tabular presentations were used to compare predicted hours of violations of the state water quality standards for swimming and boating. Hours of violation were compared for baseline conditions, baseline conditions for non-CSO pollutant sources only (stormwater, dry weather, boundary conditions), the recommended plan, and the recommended plan considering CSO sources only. A combination of project-specific and system-wide cost performance curves were used to demonstrate that the MWRA's CSO control plan provides the maximum pollution reduction benefits reasonably attainable and complies with EPA's national CSO control policy using the demonstration approach.

The percent annual compliance for the bacteria standard for swimming (200 colonies per 100 milliliters) was calculated to estimate the impact that the remaining untreated CSO discharges would have on water quality. The magnitude of each of the untreated discharges was quantified based on discharge volume from each outfall in the receiving water segment for those storm events in the typical year that cause overflows. Hours of violation associated with untreated discharges were conservatively assigned based on the hours of violation associated with the 1-year, 24-hour storm, since none of the untreated CSO outfalls discharge during the 3-month, 24-hour storm except in one of the 14 receiving water segments (Fort Point Channel).

RESULTS

MWRA's demonstration approach included the results of both technology-based and water quality-based evaluations performed for all receiving water segments. This section presents an example of the technology-based evaluations, followed by the results that show how the overall performance of the recommended plan complies with demonstration approach criteria.

Example of Technology-based Evaluation

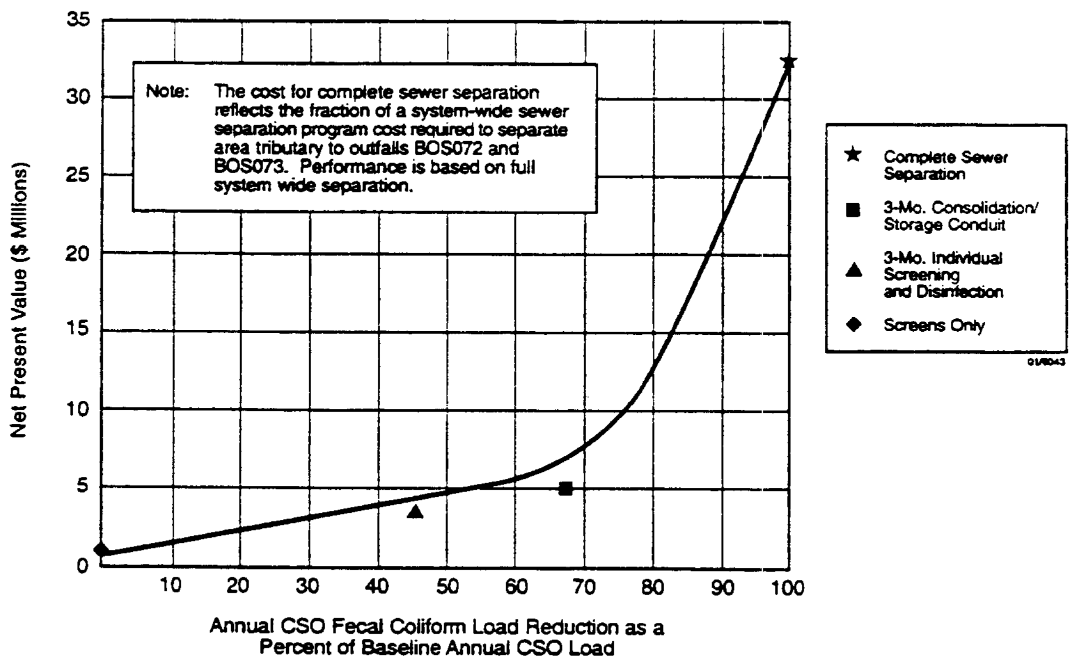
The technology-based evaluations demonstrated that the preferred alternatives represented the best available technology (BAT) economically achievable for each outfall. The results of the evaluations performed to select controls for two adjacent outfalls (BOS072 and BOS073) discharging to the Fort Point Channel receiving water segment are used to illustrate the evaluation process.

Fort Point Channel is a narrow, shallow embayment at the upper part of Boston's Inner Harbor. It is classified as Class SB-fishable/swimmable with restricted shellfishing. No shellfish resources have actually been identified within the channel and sensitive areas that support critical uses, such as swimming, are not located along the channel. Land uses in the vicinity of the channel are a mix of industrial, seafood handling, transportation, and parking. Seven untreated CSOs discharge to Fort Point Channel. No upstream sources or boundary conditions were identified for this receiving water segment. CSOs are the predominant source of fecal coliform bacteria, BOD, and nutrients for the 1-year, 24-hour storm and on an annual basis.

Using preliminary model simulations and system knowledge, four control technologies were initially eliminated from further consideration for outfalls BOS072 and BOS073: CSO relocation, local sewer separation, interceptor relief, individual or consolidated storage tanks, or primary treatment facilities. Following further screening based on cost, performance, construction risks, water quality, and social and environmental impacts, four alternatives were carried forward for detailed evaluations. These included: area-wide sewer separation, a consolidation/storage conduit sized for the 3-month, 24-hour storm, individual screening and disinfection facilities, and individual floatables control. Alternatives for outfalls BOS072 and BOS073 were grouped with alternatives for other CSO outfalls in the receiving water segment to facilitate assessment of overall water quality impacts. The range of controls evaluated for the receiving water generally reflected the range of controls for each outfall. Selection of a preferred alternative was based on the results of the cost/performance evaluations and the rating and ranking methodology.

Figure 1 shows the comparison of annual fecal coliform bacteria load reduction as a percent of baseline annual CSO load for BOS072 and BOS073. The "knee of the curve" indicates that the most cost-effective alternative for controlling fecal coliform bacteria was consolidation/storage of the 3-month, 24-hour storm. Curves for TSS and BOD yielded the same result. Curves showing the percent pollutant removal compared to baseline total receiving water loads from all sources also supported consolidated storage as the appropriate level of control. While complete sewer separation would eliminate CSO discharges in Fort Point Channel, the resulting increase in stormwater loads would cause a decrease in the removal of fecal coliform bacteria compared to consolidation/storage and a net increase in total TSS and BOD loads.

FIGURE 1. NET PRESENT VALUE VS ANNUAL CSO FECAL COLIFORM REDUCTION FOR BOS072 & BOS073



The rating and ranking method was also used to identify a preferred alternative for Fort Point Channel. This method included rating water quality impacts and costs for each alternative. Siting impacts were not rated. Table 1 shows the cost and water quality impact rank orders for the Fort Point Channel alternatives, including CSO controls for outfalls BOS072 and BOS073. The number 1 denotes the highest rank. While there was only minor differentiation among alternatives, the alternative that included the consolidation/storage conduit for outfalls BOS072 and BOS073 had the highest overall rank. Since both the cost/performance and ranking

TABLE 1. SUMMARY OF ALTERNATIVE EVALUATION RANKINGS FOR THE FORT POINT CHANNEL

CSO Control Alternative	Cost Rank	Performance/ Water Quality Impact Rank	Sum of Rankings
Complete Sewer Separation	3	1	4
Control of 3-Month Storm (storage/detention/ treatment) Storage/Consolidation Conduit BOS072, BOS073	2	1	3
Control of 3-Month Storm (screening/disinfection) Individual Screening/Disinfection BOS072, BOS073	2	2	4
Floatables Control	1	3	4

methodologies supported the consolidation/storage conduit for outfalls BOS072 and BOS073, this was the preferred alternative selected. Facilities planning efforts then involved further evaluations of alternatives for siting and construction of the conduit, as well as comparisons of costs, construction risks, and environmental impacts.

Optimization of the Preferred Alternative

The preferred alternative for outfalls BOS072 and BOS073 was construction of a 1,500-foot-long, 10-foot-diameter consolidation/storage conduit. While the original intent of the storage conduit was to capture the 3-month, 24-hour storm, siting issues related to locating tunnel shafts resulted in the conduit being of sufficient size to capture and store the volume of combined sewage generated from all but two storms in a typical rainfall year. Stored flows would be pumped back to the interceptor system once wet weather flows in the system subsided. Flows in excess of the conduit storage capacity would receive floatables control and continue to discharge from the outfalls to Fort Point Channel.

The feasibility of optimizing the preferred alternative to provide a higher level of CSO control was investigated. Optimization would involve providing either a larger storage volume, or combining the storage conduit with another CSO technology such as disinfection. The cost-effectiveness, performance, and receiving water benefits for three incrementally higher levels of control were evaluated. The benefit of removing more pollutants from the waterbody was assessed based on cost-effectiveness, i.e., the unit cost to remove the increment of pollution, and on the relationship between providing incrementally higher levels of control and attaining designated uses.

Table 2 presents the cost and performance of existing baseline conditions, the preferred alternative, and the three higher levels of control evaluated. Based on the net present value per annual pollutant load removed, the preferred alternative is the most cost-effective level of CSO control in terms of achieving control of fecal coliform bacteria, TSS, and BOD, followed by the 11-foot-diameter, 1,500-foot storage conduit. The higher level of control would cause a 7 percent increase in net present value cost for an additional 5 percent reduction in annual pollutant load, showing that the increased cost would be proportional to increased performance.

Model results indicated that under the recommended plan, the bacteria standard for boating is violated during the 3-month, 24-hour storm near outfalls BOS072 and BOS073. The standard for swimming is violated in the remainder of the channel. These violations are due to stormwater discharges, since only treated CSO flow from another outfall is discharged into the channel for this size storm. The model also showed that even total elimination of CSO discharges from the outfalls would not result in attainment of the boating standard during the 1-year storm. Since even total elimination of CSO discharges would not change the level of uses attained in the Fort Point Channel during wet weather due to stormwater, incrementally increasing the project cost to

TABLE 2. COST EFFECTIVENESS OF INCREMENTALLY HIGHER LEVELS OF CSO CONTROL FOR OUTFALLS BOS072 AND BOS073

Alternative	Annual Activation Frequency		Percent Reduction in Annual Pollutant Load			Capital Cost ($ millions)	Net Present Value per Annual Pollutant Load Removed		
	BOS072	BOS073	Fecal Coliform	BOD	TSS		Fecal Coliform ($/count x 10^9)	BOD ($/lb)	TSS ($/lb)
Baseline conditions	10	19	--	--	--	--	--	--	--
10-ft diameter, 1,500-ft long storage conduit	2	2	80	80	80	$13.5	$85	$2,670	$1,490
10-ft diameter, 1,500-ft. long storage conduit with disinfection	2	2	96.7	93	93	$18.4	$97	$3,175	$1,769
11-ft. diameter, 1,500-ft. long storage conduit	2	2	85	85	85	$14.3	$86	$2,685	$1,496
12-ft. diameter, 1,895-ft. long storage conduit	0	0	100	100	100	$17.2	$88	$2,752	$1,534

achieve a proportional incremental increase in CSO control was not recommended. It was noted, however, that the concept of incrementally increasing the size of the storage conduit should be re-evaluated based on more detailed, site-specific information to be developed during design.

Results of Water Quality-Based Evaluations

Results of the water quality assessments performed under the demonstration approach show that MWRA's recommended CSO control plan fulfills the criteria set by EPA for a successful demonstration.

Criterion i: The planned control program is adequate to meet WQS and protect designated uses, unless WQS or uses cannot be met as a result of natural background conditions or pollution sources other than CSOs

The recommended CSO control plan complies with state water quality standards and protects designated uses in all 14 receiving water segments, either by elimination or relocation of CSOs, or by meeting the requirements for the state's water quality classifications of Class B(CSO) or Class SB(CSO) for minimally impacted waters, or by using a variance designation until more water quality information is available.

Performance of CSO control alternatives was evaluated in terms of receiving water impacts. Based on the existing designated uses and associated water quality parameters identified for each receiving water segment, a number of measures were identified to quantify the impact of the CSO control alternatives on water quality. Typical output from the receiving water models used in evaluation of CSO control alternatives included the duration of violation of fecal coliform bacteria standards, predicted fecal coliform bacteria density (broken down by source), and fecal coliform bacteria density isopleths. The modeling analyses focused on fecal coliform bacteria as the parameter of concern, since designated uses to be protected are shellfishing, swimming, and boating. The results of fecal coliform bacteria evaluations were summarized by major basin to demonstrate compliance with EPA criteria for a successful demonstration.

The results of Boston Harbor receiving water model analyses for fecal coliform bacteria under 3-month, 24-hour design storm conditions for baseline conditions - all sources, baseline conditions - non-CSO sources only, and the recommended plan - all sources showed that under baseline conditions, the swimming and boating bacteria standards are violated in several areas of the harbor. However, when baseline conditions - non-CSO sources only and the recommended plan results were compared, the fecal coliform bacteria densities were virtually the same. This means that following implementation of the recommended plan, remaining violations will be predominantly due to impacts from non-CSO sources.

In the Charles River, violations of both the swimming and boating bacteria standards occurred under all conditions, and as in Boston Harbor, the model showed that following implementation of the recommended CSO control plan, remaining violations will be predominantly due to non-CSO impacts. Of particular interest in the Charles River were the dry weather fecal coliform bacteria concentrations that violate the swimming standard all the time. During wet weather, stormwater and upstream sources contribute a major percentage of fecal coliform bacteria to the river basin, while CSOs are not a significant source. The recommended CSO control plan meets *Criterion i* for the Charles River, since significant pollution sources from the upstream Charles River watershed prevent water quality standards from being met even during dry weather. Because efforts are on-going to identify and control non-CSO sources, the regulatory option for a short-term variance from water quality standards for CSO discharges into the Charles River was deemed to be appropriate until more information on the non-CSO sources is available.

> *Criterion ii: The CSO discharges remaining after implementation of the planned control program will not preclude the attainment of WQS or the receiving waters' designated uses or contribute to their impairment. Where WQS and designated uses are not met in part because of natural background conditions or pollution sources other than CSOs, a total maximum daily load, including a wasteload allocation and a load allocation, or other means should be used to apportion pollutant loads*

Hours of violation of the fecal coliform bacteria standards for swimming and boating from the 3-month, 24-hour storm for baseline conditions and for the recommended plan were calculated. For all receiving water segments, the hours of violation after implementation of the recommended plan due to CSO-only discharges is zero for both the swimming and the boating standards. When the "recommended plan CSO-only" results were compared to the "baseline conditions non-CSO-only" results, it was clear that the violations of the bacteria standards remaining after implementation of the recommended plan will be caused by the impacts of non-CSO sources.

Table 3 presents the hours of violation of the bacteria standards for swimming and boating due to the 1-year, 24-hour storm for each of the receiving water segments. Table 3 also presents the annual percent compliance with the swimming standard, assuming each discharge event in the typical rainfall year had the same impact as the 1-year, 24-hour storm. As shown in Table 3, the percent compliance with water quality standards, even using the extreme case based on hours of violation caused by all sources in the 1-year, 24-hour storm, is greater than 95 percent in all receiving water segments. Using hours of violation based on CSO-only for the 1-year, 24-hour storm, the compliance for all segments is greater than 98 percent.

> *Criterion iii: The planned control program will provide the maximum pollution reduction benefits reasonably attainable*

The planning process has resulted in selecting CSO controls that will provide the maximum pollution reduction benefits reasonably attainable for each receiving water segment affected by CSOs. The recommended plan will maximize capture of combined sewage flow and provide treatment at the MWRA Deer Island treatment plant or MWRA CSO treatment facilities for almost all of the total annual combined sewage volume. Implementation of the recommended CSO control plan will reduce the total annual volume of CSO discharges compared to baseline conditions by about 58 percent and will reduce the annual volume of untreated CSO discharges by 95 percent. Of the annual CSO volume remaining after implementation of the recommended plan, 95 percent will be treated at MWRA CSO facilities prior to being discharged. When conveyance to the Deer Island treatment plant is considered, 99.7 percent of the total annual combined sewage volume will be captured and treated under the recommended plan.

As shown by Figure 2, the most significant reductions in CSO volume and pollutant discharges, including BOD, TSS, and fecal coliform bacteria, are predicted to have occurred from 1988 to 1997, which is consistent with

TABLE 3. HOURS OF VIOLATION OF BACTERIA STANDARDS FOR 1-YEAR, 24-HOUR STORM (based on 96-hour simulation)

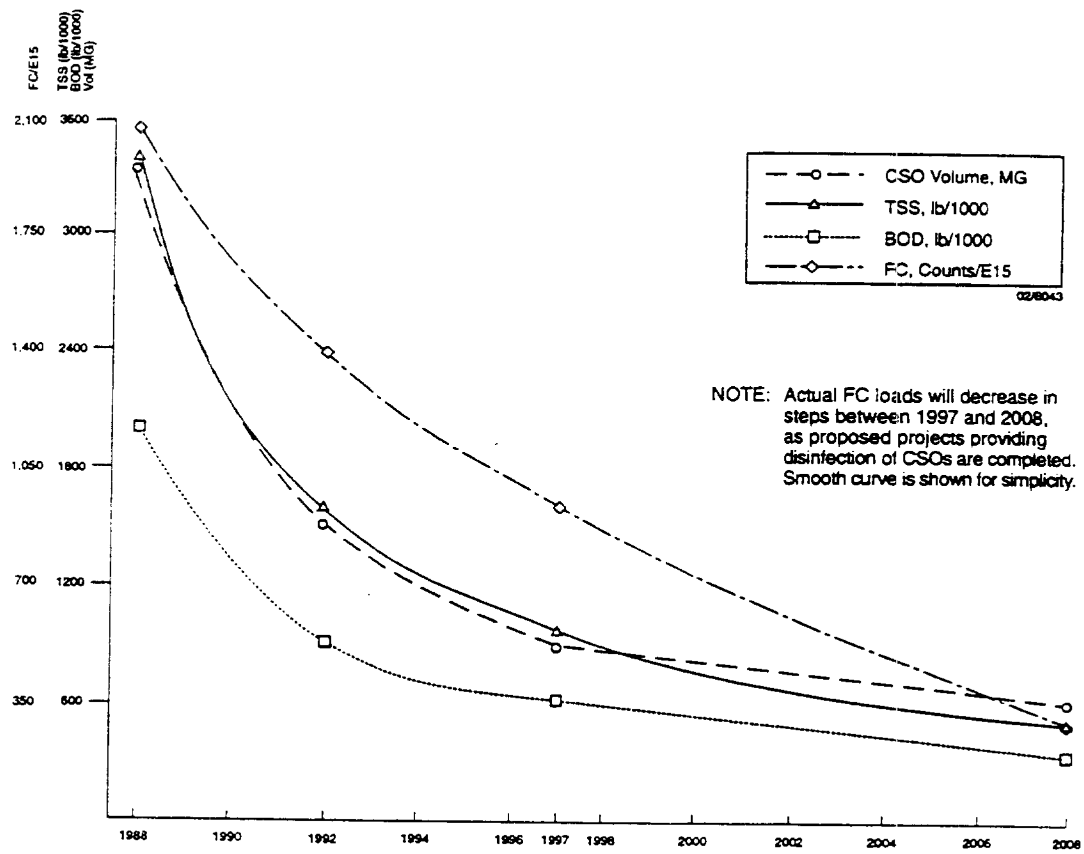
Receiving Water Segment	Hours of Violation of Swimming/Boating Standards[1] for Fecal Coliform				Annual Compliance % All sources vs CSO only
	Baseline Conditions[2] (all sources)	Baseline (non-CSO only)	Recommend Plan[2] (all sources)	Recommend Plan (CSO only)	
North Dorchester Bay	20 / 6	16 / 0	0 / 0	0 / 0	100[4]
South Dorchester Bay	17 / 0	17 / 0	23 / 0	0 / 0	100[4]
Neponset River	71 / 35	68 / 33	70 / 33	0 / 0	100[4]
Constitution Beach	27 / 3	27 / 1	27 / 1	0 / 0	100[4]
Upper Charles River	96 / 84	96 / 84	96 / 84	0 / 0	98.9 - 100[5]
Lower Charles River[3]	88 / 56	88 / 50	88 / 56	0 / 0	98.0 -100[5]
Alewife Brook	96 / 90	96 / 90	96 / 90	0 / 0	95.6 - 100[5]
Upper Mystic River	90 / 70	90 / 60	90 / 64	0 / 0	100[6]
Upper Inner Harbor	37 / 14	7 / 0	17 / 0	8 / 0	99.0 - 99.5
Lower Inner Harbor	28 / 0	0 / 0	8 / 0	0 / 0	99.6 - 100
Mystic/Chelsea	50 / 17	49 / 16	49 / 15	0 / 0	97.8 - 100
Reserved Channel	30 / 16	0 / 0	0 / 0	0 / 0	100[6]
Fort Point Channel	48 / 34	29 / 14	33 / 18	25 / 13	98.5 - 98.9

(1) Swimming standard = 200 # / 100 ml; Boating standard = 1000 # / 100 ml.
(2) Includes boundary, stormwater, dry weather, and CSO sources.
(3) Includes Back Bay Fens.
(4) CSO discharges are eliminated.
(5) These segments violate the bacteria standard for swimming all the time if dry weather components are included.
(6) Treated discharges only.

system improvements that were undertaken during that time. The substantial reduction in CSO volumes are primarily related to increases in pumping capacity at the Deer Island treatment plant. Additional reductions associated with the MWRA CSO control plan will occur from 1997 to the year 2008, by which time reductions on the order of 80 to 90 percent will be achieved for CSO discharge volume, BOD, TSS, and fecal coliform bacteria.

With 95 percent of the flow being captured and conveyed to Deer Island for secondary treatment, further reductions in CSO volume or pollutant loads after the year 2008 would have relatively little significance in terms of water quality improvement, and would be even less significant when compared to potential total load reductions to the receiving waters. If further improvements to receiving water quality are to be realized, these improvements must come from the control of non-CSO sources. Higher levels of CSO control beyond those recommended in the CSO control plan would not achieve measurable receiving water benefits.

FIGURE 2. ANNUAL VOLUME AND POLLUTANT LOADS, CSO ONLY



Criterion iv: The planned control program is designed to allow cost effective expansion or cost effective retrofitting if additional controls are subsequently determined to be necessary to meet WQS or designated uses

Given the level of control that the recommended CSO control plan will achieve, additional controls will not likely be justified until substantial reduction in non-CSO sources of pollutants are achieved. Where feasible, the recommended plan would allow for providing higher levels of CSO control if necessary. For example, where hydraulic relief is currently recommended, storage and/or treatment units could be added in the future.

DISCUSSION

MWRA used the demonstration approach because detailed information on the combined sewer system had been gathered and the accuracy of models to evaluate system performance and water quality impacts from CSO and non-CSO sources of pollution had been verified. According to EPA's CSO policy, the demonstration approach was intended to provide flexibility in developing CSO plans, such that a plan could be shown to meet water quality standards while not necessarily satisfying the criteria under the policy's presumption approach. Analyses conducted during facilities planning actually showed that MWRA surpasses the presumption approach requirements, even before the CSO control plan will be fully implemented.

MWRA's CSO control plan meets the first presumption criterion by reducing the activations of untreated CSOs to no more than an average of four events per year on an annual average basis in the typical rainfall year.

The results of system modeling also showed that the percent capture, or the percentage of flow entering the combined sewer system during periods of precipitation which is captured for treatment, steadily improved from 1988 to 2008. In 1992, when initial improvements at the Deer Island treatment plant were near completion, but implementation of major conveyance system improvements and construction of the new Deer Island treatment plant were only beginning, MWRA nearly achieved the 85 percent capture cited in the second criterion under the presumption approach. Under 1997 conditions, assuming full pumping capacity at the Deer Island plant, MWRA exceeds the 85 percent capture criterion. Additional combined sewage capture by the year 2008 will be achieved when, under the recommended CSO control plan, 95 percent of the flows entering the system will be treated at the Deer Island plant to meet secondary effluent limits. The third presumption criterion requires that no less than the mass of pollutants causing water quality impairment for the percent reduction in volume achieved be eliminated or reduced. Since 95 percent of the combined sewage flows will receive secondary treatment, this third criterion will also be met.

Although MWRA meets not one but all of the criteria under EPA's presumption approach, the demonstration approach provided the advantage of tailoring CSO controls to specific conditions in distinctly defined receiving waterbodies. Greater emphasis could be focused on protecting waterbodies that support sensitive uses rather than making across-the-board reductions without considering site-specific water quality and existing designated uses.

CONCLUSIONS

The MWRA's CSO control plan complies with the requirements for a successful demonstration under EPA's national CSO policy, confirming that water quality standards will be met and designated uses protected. Using the demonstration approach involved comprehensive and detailed assessments to accurately characterize receiving waters, CSO and non-CSO sources of pollution, and associated water quality impacts. By developing the plan according to the demonstration approach, CSO controls were selected to address site-specific conditions. The demonstration approach not only resulted in an environmentally sound plan that provides an appropriate level of CSO control, but also a cost-effective plan that acknowledges the need to consider ratepayer interests.

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COMBINED SEWER OVERFLOW STUDY IN CLEVELAND'S WESTERLY DISTRICT

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ABSTRACT

The Northeast Ohio Regional Sewer District (NEORSD) is the agency responsible for wastewater treatment in the Cleveland area. Its jurisdiction includes interceptor sewers, three wastewater treatment plants, and combined sewer overflows (CSOs). NEORSD's National Pollutant Discharge Elimination System (NPDES) permit requires development of a CSO control plan.

The Westerly district of NEORSD's service area is tributary to the Westerly Wastewater Treatment Plant (WWTP). It consists of approximately 40 km^2 (10,000 acres), of which 75 percent are served by combined sewers. It is entirely located on the west side of the City of Cleveland. The combined sewer area contains 4 interceptor sewers, 70 static regulators, 8 hydrobrakes, 8 automated regulators, and 26 CSO outfalls. Lake Erie, Cuyahoga River, Rocky River and Big Creek receive CSO discharges from this area during wet weather. When peak wet weather flows exceed the capacity of the Westerly WWTP, the overflows are routed to the adjacent Combined Sewer Overflow Treatment Facility (CSOTF).

NEORSD is undertaking a study that will result in specific recommendations for a long-term wet weather control plan in the Westerly district. This paper focuses on aspects of the study that have been completed and on the results obtained. An extensive monitoring program including more than 100 flowmeters was conducted during the spring of 1997. The separately sewered area, which has over-under sewers, was included in the investigations. Data management utilizes a Geographical Information System (GIS). A detailed HydroWorks™ model of the collection system is fully integrated into the GIS. Monitoring and analysis of the operation of CSOTF was performed.

Based on results of the data collected, several projects have been identified for early implementation. These projects include location and removal of sources of dry weather contamination and prevention of river water inflow into the sewer system. While these projects are underway, a range of long-term alternatives are being evaluated for an overall wet weather plan for the Westerly district.

INTRODUCTION

In accordance with its NPDES permit, the NEORSD must develop a long-term combined sewer overflow control plan (LTCP). Efforts towards this plan were initiated in the early nineties, when the NEORSD conducted a Phase I CSO study of its entire service area. Phase II studies are now being conducted in the service areas tributary to each of the three District wastewater treatment plants. This paper describes the study being conducted in the Westerly district. The study was initiated in late 1996 and is scheduled for completion by the end of 1998. The study area is shown in Figure 1.

The ultimate goal of the Westerly district CSO study is the reduction of the impact of combined sewer overflows in the receiving waters. The study also intends to devise solutions to alleviate basement flooding whenever possible.

A thorough understanding of the Westerly district system is paramount to the development of this study. The *Methodology* section describes the technologies and procedures utilized to attain this understanding and summarizes the methods utilized to analyze and manage the information about the Westerly district. Results of the data collection and analysis efforts are then presented, along with a description of projects

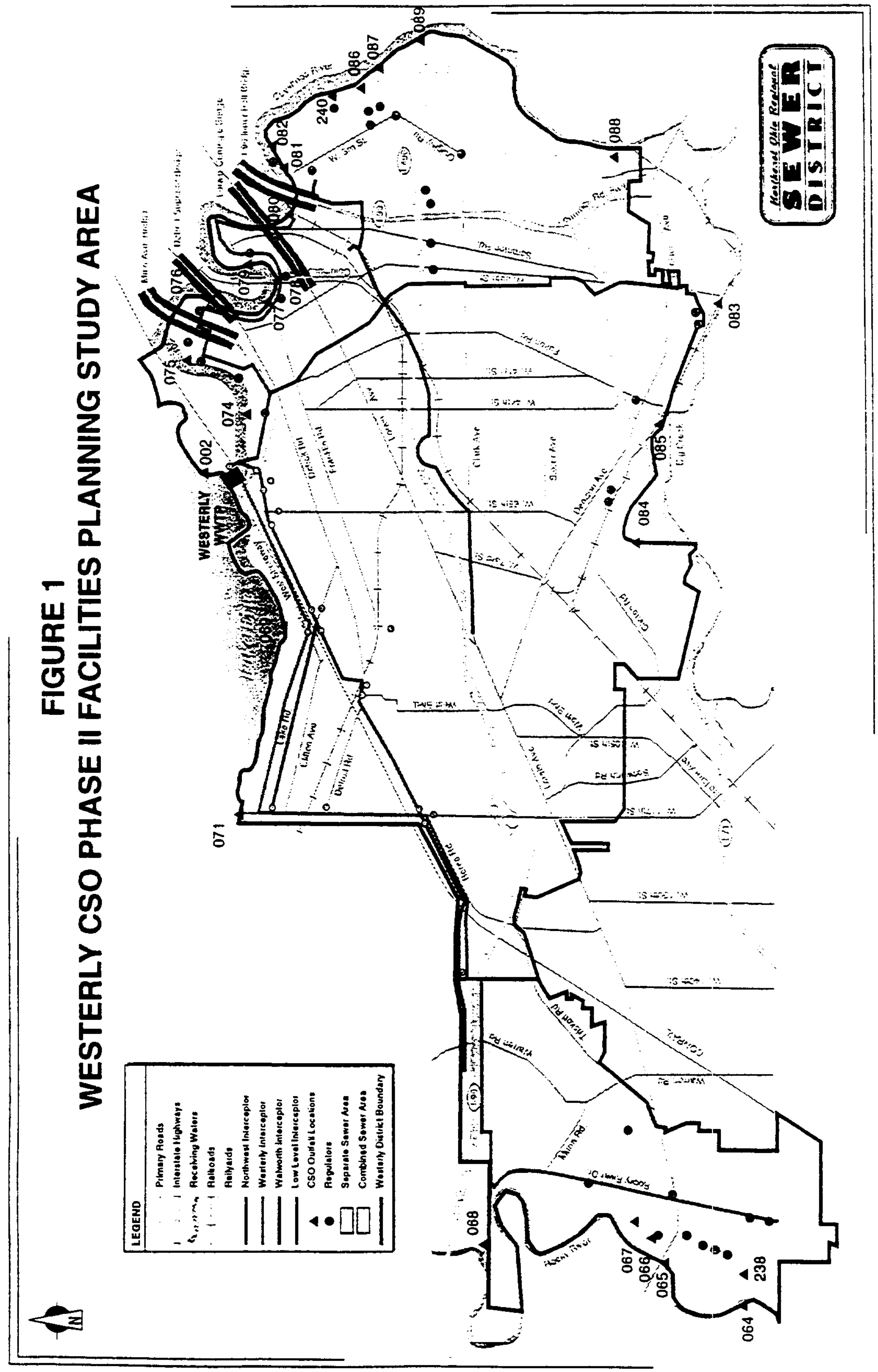
FIGURE 1
WESTERLY CSO PHASE II FACILITIES PLANNING STUDY AREA
LEGEND
Primary Roads
Interstate Highways
Receiving Waters
Railroads
Railyards
Northwest Interceptor
Westerly Interceptor
Walworth Interceptor
Low Level Interceptor
CSO Outfall Locations
Regulators
Separate Sewer Area
Combined Sewer Area
Westerly District Boundary
WESTERLY WWTP
Northeast Ohio Regional
SEWER
DISTRICT
002
064
065
066
067
068
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240

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being implemented based on the results. The *Discussion* section contains the approach for evaluating alternatives for CSO control and a summary of public information activities. The paper concludes with the status of the study as of March, 1998, and a summary of its most relevant aspects.

METHODOLOGIES

Flow Monitoring

The general goal of the flow monitoring program was to provide an understanding of flow characteristics in the Westerly collection system. Specifically, the program provided data for calibration of the sewer system hydraulic model, for SSES tasks such as determination of infiltration and inflow (I/I) components within the separate sanitary sewer areas, and to assist in the quantification of study area pollutant loads.

In total, 108 flow monitors and 7 rain gauges were installed within the Westerly district. Primary flow monitoring and rain gauging were conducted from March 3 through June 16, 1997. A subset of monitors (11 total) remained in place until August 27 to further evaluate the performance of the WWTP and CSOTF during larger rain events. The meters recorded flow measurements every 5 minutes throughout the field investigations.

Water Quality Sampling

Sampling of outfalls to study area receiving waters was conducted during both dry and wet weather. During dry weather, field investigations were performed to determine flows and pollutant loads from outfalls in the Westerly drainage area. These investigations included a shoreline reconnaissance survey to locate the outfalls. Flows were measured and samples were taken for any outfalls found flowing during dry weather. Flows were sampled for bacteria and ammonia as indicators of possible contamination from wastewater.

Outfall quality monitoring during wet weather was performed to allow quantification of pollutant concentrations and loads entering the receiving waters. Eight outfalls in the Westerly system were monitored for water quality during five rainfall events. Both automated time-weighted composite and grab samples were collected at each site for analysis. Parameters analyzed included bacteria, BOD, TSS, nutrients and metals. Each sampling site was equipped with an ADS flow meter for measuring depth and velocity and an Isco Model 3700 sampler for collecting water quality samples. During each storm event, the Isco Model 3700 sampler was manually activated and collected a 350 ml sample in a glass vessel every 15 minutes for 6 hours (24 samples).

The eight sampling sites were selected to characterize discharges from outfalls that had large amounts of storm water (i.e., from highway drainage) or from areas with largely separate over-under sewers. An extensive database of quality from outfalls with mostly combined sewers was already available from a previous study (Havens & Emerson, 1994). This approach allowed cost-effective characterization of all of the major types of pollutant loads from the Westerly district.

Receiving Water Assessment

The Westerly district is interesting in that it drains to four different receiving waters. In each case, there are numerous sources of pollution other than CSOs entering upstream (or, in the case of Lake Erie, up-wind). The pollutant loads from the study area (CSO as well as storm water) were estimated and compared to background or upstream pollutant loads.

CSOTF Evaluation

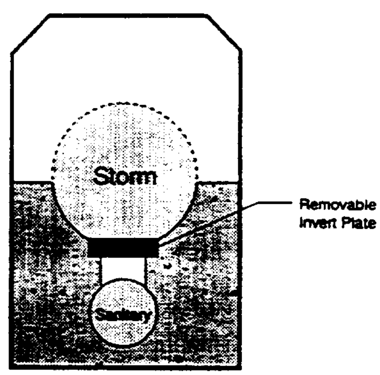
The flow monitoring and sampling program also assessed the effectiveness of CSOTF. CSOTF stores and treats wet weather flows that exceed the Westerly WWTP influent capacity. Six storms were intensively monitored and sampled to provide flow and mass balance information. From this, pollutant removal effectiveness was defined. These results are presented in detail in a separate technical paper (McMasters et al, 1998).

Sewer System Evaluation Survey (SSES) Information

Existing sewer system information was collected from various sources. The NEORSD maintains sewer plans, profiles, and structural drawings for all interceptors and much of the sewer system. Drawings which were not available from this source were obtained from the City of Cleveland, who owns and maintains the local sewers. In 1978, Cuyahoga County produced county-wide aerial maps which were used as base maps by the City of Cleveland to produce area-wide sewer maps showing sewer alignments, types and sizes. Regulator schematic drawings and drainage area boundaries were obtained from the NEORSD Phase I CSO Study. In all, about 1,000 drawings were cataloged and reviewed. This emphasizes the importance of developing data management methods for approaching large area-wide projects.

FIGURE 2

TYPICAL OVER-UNDER SEPARATE SEWERS



OVER-UNDER

A field inspection program was carried out to check and confirm the accuracy of existing information for mapping, determine the condition of the sewers and obtain information necessary for developing the hydraulic model such as flow direction, connectivity, and elevations.

Selected portions of the separate sewered area were evaluated for infiltration/inflow. About half of this separate sewer system has a unique design common in the Greater Cleveland area known as "invert plate sewer" or "over-under sewer." In this configuration the storm sewer is directly above the sanitary sewer. At manholes, a removable cast iron plate which forms the invert allows access to the sanitary sewer. A typical over-under sewer design is shown in Figure 2.

The separate system was inspected in detail. Flow monitoring results were used to rank suspect I/I stretches. Dye testing with televising was used to investigate I/I sources. A total of over 7,700 meters (25,000 feet) of sanitary sewer ranging in diameter from 20.32 to 45.72 cm (8 to 18 inches) in 145 pipe reaches were televised.

Geographical Information System (GIS)

The extensive amount of data generated by this project required effective management. In addition, NEORSD routinely produces presentation-quality maps for its facilities planning projects. Utilizing a GIS to manage data was a natural choice for the needs of the project.

Cuyahoga County planimetric maps based on 1993 aerial photos were translated into ArcView® format and served as the base maps for the GIS. Local sewers were digitized in AutoCAD® and imported into ArcView®. Under the Westerly District Interceptors Inspection and Evaluation Project (Duke et al, 1998), data were collected on the NEORSD interceptor sewers and outfalls. This data was combined with the local sewer data to form a complete physical representation of the Westerly district in the GIS.

Digital databases containing manhole and pipe information were linked to the ArcView® GIS. Other databases include information on the over-under sewers (condition of each manhole plate), locations of flowmeters, and water quality sampling results. Spatial information such as land use, ward boundaries, and neighborhood boundaries were also included in the GIS.

The ArcView® GIS was developed to facilitate data storage for both mapping and hydraulic modeling tasks.

HydroWorks™ Collection System Model

The hydraulic model for Westerly needed to include all interceptors and outfalls, as well as major trunk sewers in the combined system, all over-under sewers (down to 20.32 cm [8-inch] pipes) in the separate system, all hydrobrakes and both static and automated regulators. The HydroWorks™ model was selected because it could simulate this system in a stable and robust manner. HydroWorks'™ capability to simulate automated flow control structures incorporating the PID control process was particularly important. The GIS was used for handling the large volume of collection system data during the model development and as an input and output processor.

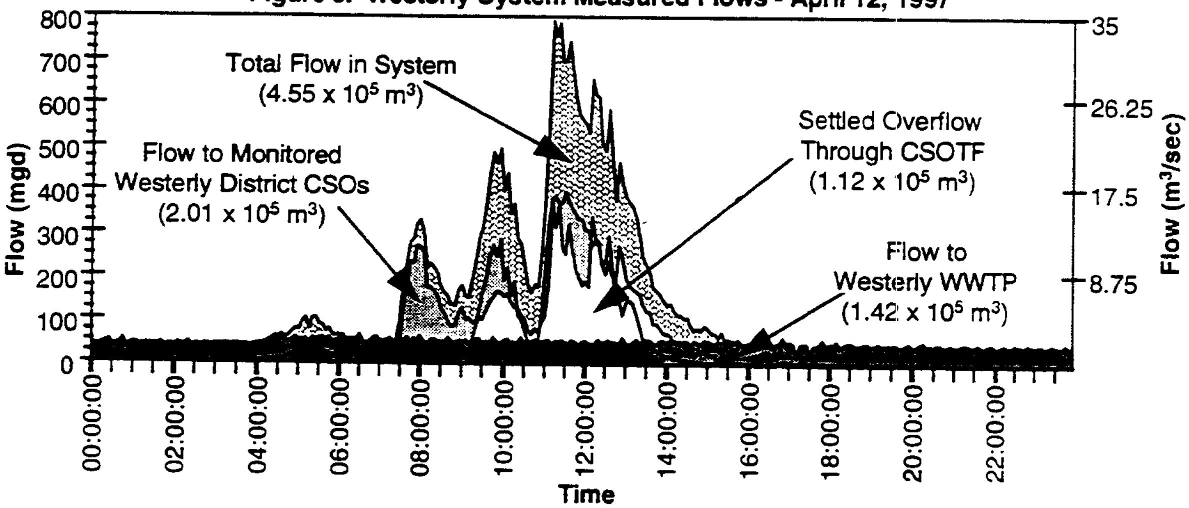
RESULTS

Flow Monitoring

The flow monitoring program successfully monitored over 15 storm events, with the majority of the flow meters being operational for most of the storm events. The data are being used mainly to understand flows in the system and for calibration of the HydroWorks™ collection system model.

The measured flows were analyzed to determine overall volumes in the system for various storm events. One example of this is shown in Figure 3, in which total volumes for the storm of April 12 are estimated. The volume treated at the WWTP, at CSOTF, and the volume overflowing are estimated based on the flow data. This indicates that the treatment facilities in the Westerly system already allow treatment of about 56 percent of the wet weather volume during the one-day period. This does not include storage in the system (autoregulators and hydrobrakes) and in the CSOTF tanks, which results in higher capture.

Figure 3. Westerly System Measured Flows - April 12, 1997



Dry Weather Outfall Sampling Results

The results of the dry weather outfall reconnaissance and sampling are summarized in Table 1. Only a small percentage of the total number of outfalls showed evidence of possible contamination from wastewater. Each of the outfalls was traced upstream by NEORSD staff to determine potential sources of contamination. Letters were written to responsible parties, and the problems are in the process of being corrected. It should be noted that the total pollutant load from these dry weather sources was minimal in comparison to background or upstream loads, and can be neglected during facilities planning.

Table 1. Dry Weather Outfall Investigations

Receiving Water	Outfall Data Summary				
	Outfalls Found	Outfalls Flowing		Outfalls Needing Further Investigation*	
		Number	Percent	Number	Percent
Cuyahoga River	140	19	14	9	6
Lake Erie	37	1	3	1	3
Rocky River	71	24	34	15	21
Total	248	44	18	25	10

** Ammonia ≥1 mg/l and/or fecal coliform ≥ 10,000 MPN/100ml*

Wet Weather Outfall Sampling Results

Concentrations of parameters measured during this project (mainly in storm water) are compared in Table 2 with CSO concentrations previously measured. Results indicate that generally lower concentrations were found in storm water than in CSO. These values are being used to estimate pollutant loads based on the CSO and storm water volumes computed by the hydraulic model.

Table 2. Comparison of Outfall Quality

Parameter (Unit)	Mean Concentration - All Storms and Sites	
	Phase II Project Data (Mainly Storm water)	Phase I Project Data (Mainly CSO)
BOD_5 (mg/l)	12.1	81
TSS (mg/l)	58	444
FC (MPN/100ml)	33,500	855,000
NH_3 (mg/l)	0.8	4.3

Receiving Water Assessment

This assessment indicated that upstream or storm water loads, rather than Westerly district CSO loads, were the dominant factors influencing attainment or non-attainment of water quality standards in the Cuyahoga River, Rocky River and Big Creek. (CSO loadings to Lake Erie were insignificant.) The CSO loadings were either larger or of the same order of magnitude as upstream dry weather loadings (due to large upstream drainage areas). However, control of wet weather sources other than CSO was determined to be equally or more important to water quality conditions.

In consideration of the above finding, rigorous water quality modeling is not being used for the evaluation and selection of CSO control alternatives in the Westerly district. Instead, models are being used to demonstrate that the selected CSO control alternative does not in itself prevent attainment of water quality standards as required by the demonstration approach of the CSO policy. Incremental impacts resulting from the LTCP are being calculated and compared to existing conditions and conditions without CSO overflows (the Ohio Strategy requires that the control option of eliminating all CSOs be considered) using existing models and design storms to evaluate incremental water quality impacts.

I/I Results

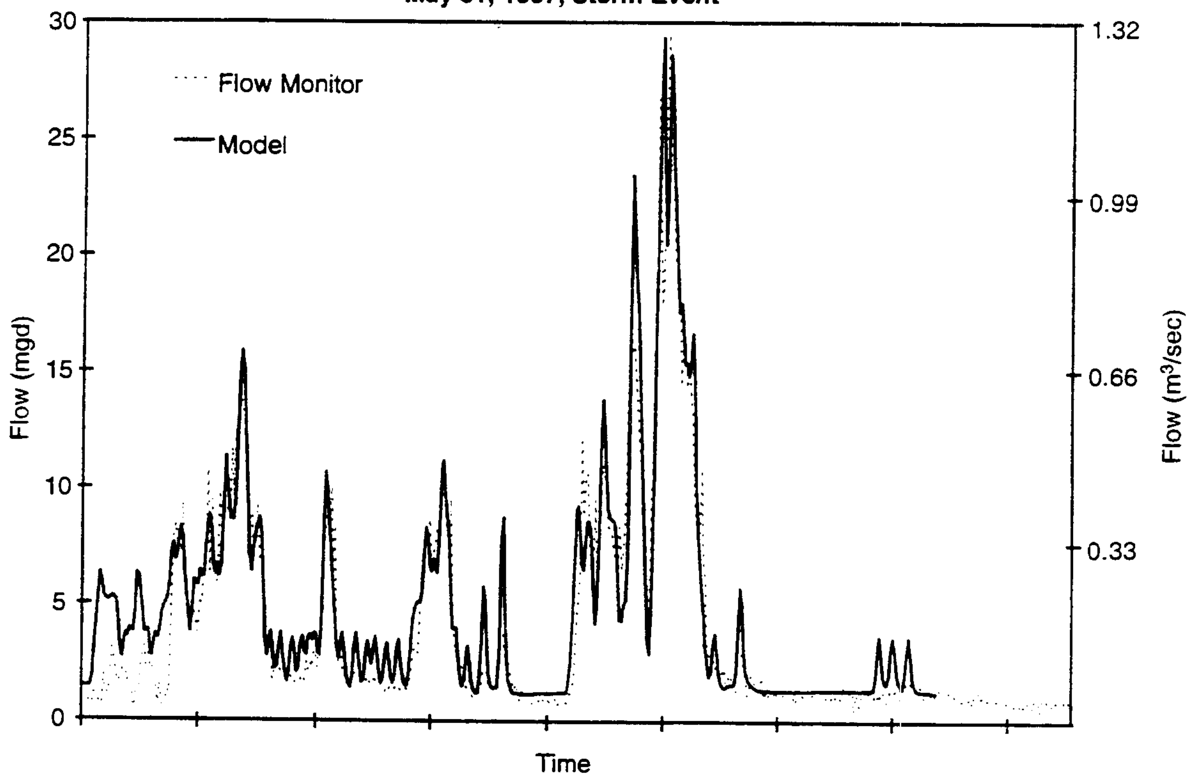
Out of 265 manholes with invert plates, 140 were intact and positioned properly. The remaining 125 plates (47%) were either damaged (45), seated improperly (24), or missing entirely (55). The I/I investigations in these pipe stretches determined that most of the inflow — and contaminated overflows —

are the result of the condition of these invert plates. Investigation of separate sewers which are not invert plate sewers determined that inflow was largely due to private property connections. In order to effectively investigate and televise these sewers, many reaches required extensive sediment cleaning. Since basement flooding had been reported in some of these areas, the cleaning is expected to provide some relief from this condition.

HydroWorks™ Model Calibration

The approach to HydroWorks™ model calibration relies on in-depth knowledge of the collection system. Emphasis is placed on drainage system data which includes pipe attributes and land use characteristics. Calibration was carried out for dry weather and wet weather events. For the initial storm run, model results showed a good comparison against flow monitoring data. One of the calibration curves is shown in Figure 4. It depicts the event of May 31, 1997, which had a total rainfall of 2.2 cm (0.87 in.) over a 36-hour period.

Figure 4. HydroWorks Model Calibration
May 31, 1997, Storm Event



River Inflow

An unexpected finding was made during the course of the sewer system investigations. Three CSO outfalls to the Cuyahoga River were flowing into the collection system. The problem was caused by river levels being higher than the weir levels at regulators upstream of these outfalls.

A fast-track study of the affected outfalls indicated that, although the problem had been observed in a year when Lake Erie (and thus the Cuyahoga River) had reached record levels, it could persist even at lower lake levels. The study determined that transportation, pumping and treatment of the inflowing river water represented a significant cost, and that collection system capacity was being diminished by the river inflow. The cost-effective solution to control the problem would be the installation of "duckbill" valves at two of the problem sites, and the increase of the weir elevation at the regulator upstream of the third site.

Study recommendations were expeditiously adopted, and the river inflow control project is currently in its final design stages. Construction is planned for later this year.

DISCUSSION

At the time of the writing of this paper, the study team has developed a clear understanding of system characteristics. The stage is set for conducting the alternative analysis.

Traditional capital intensive solutions for the control of combined sewer overflows include increasing system storage, conveyance, or treatment capacities. In analyzing possible alternatives for the Westerly district, structures such as tunnels, basins and vortex separators will be assessed. However, special attention will be paid to optimizing the operation of the existing system. The automated regulators that are already a functional part of the system make Westerly especially suited for this type of approach.

A multicriteria approach is being employed for the analysis of potential CSO control solutions. Criteria in the analysis include capital and operational cost, effectiveness, reliability, public acceptance, maintenance complexity, and permitting issues. The weight of each criteria in alternative evaluation is being determined by assessing the importance of each criteria to NEORSD decision makers. A measure of public acceptance of each potential alternative will result from the extensive public participation program that is part of this study.

The public participation program was initiated at the local government level. Council representatives of the wards located in the study area were individually contacted and briefed on the project, as were City of Cleveland public officials engaged in functions related to wastewater. Outreach to the general public was achieved by holding public meetings at a library in the study area. Neighborhood organizations and community groups were invited to attend. In addition, flyers announcing the meetings were posted on bulletin boards throughout the study area, and advertisements appeared in community newspapers. Two of four planned meetings have already taken place, with satisfactory general public attendance. At these meetings, the public was informed of the goals, status and available results of the study, and had opportunity to ask questions and raise concerns. At the upcoming meetings, the public will be invited to comment on proposed alternatives before final recommendations are selected.

CONCLUSIONS

Now in the facilities planning stage, the Westerly study has the database and tools which will allow the development of a cost-effective LTCP. In the process of developing these data and tools, noteworthy findings, early actions, and benefits occurred:

- As a result of the study's field investigation efforts, the City of Cleveland has already received extensive information on problems with manhole invert plates, system blockages, and potential improper connections.

- During the flow monitoring effort an existing flowmeter located at the discharge of CSOTF was revamped and extensively tested, leaving CSOTF with an improved process for measuring and reporting overflows from the facility.

- Water quality investigators meticulously traced every incident of dry weather flow from outfall to source, notified the appropriate parties, and are tracking the source removal process.

- River inflow through the outfalls located in the Westerly district will soon be a problem of the past. Construction of river inflow control facilities will be well underway by the time the Westerly CSO Study Final Report is produced.

- Thanks to the public information program, residents of the study area have a forum where they can bring questions and concerns. Even when their sewer-related problems fall beyond the realm of the NEORSD, residents are educated on how to proceed towards a solution.

- NEORSD planners and engineers are making use of the Westerly District Geographical Information System even as it is still being developed.

If a project's achievement can be measured by how early the community starts reaping its benefits, the Westerly study is a success.

ACKNOWLEDGMENTS

Funding for this project was provided by NEORSD.

APPENDIX

Abbreviation	Term
BOD	Biochemical oxygen demand
cm	Centimeters
CSO	Combined sewer overflow
CSOTF	Combined Sewer Overflow Treatment Facility
FC	Fecal coliform
GIS	Geographical information system
I/I	Infiltration and inflow
km^2	square kilometers
LTCP	Long-term control plan
mg/l	Milligrams per liter
mgd	Million gallons per day
MPN/100 ml	Most probable number per 100 milliliters
NEORSD	Northeast Ohio Regional Sewer District
NH_3	Ammonia
NPDES	National Pollutant Discharge Elimination System
OEPA	Ohio Environmental Protection Agency
PID	Proportional integral differential
SSES	Sewer System Evaluation Survey
TSS	Total suspended solids
USEPA	United States Environmental Protection Agency
WEF	Water Environment Federation
WWTP	Wastewater treatment plant

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CSO PLAN OPTIMIZATION

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ABSTRACT

An approach and a tool developed to optimize long term CSO plans are proposed. The idea consists of investigating a large number of alternative CSO control measures in a global optimization problem and considering the overall CSO control performance. Alternative CSO control measures include the sewer network operating mode, the localization and sizing of the retention facilities, the transport and treatment capacities of the sewer network. The optimization tool, MED-SOM, is linked to an hydraulic/hydrologic model. It simulates the behavior of the network scanning through all possible combinations and permutations of CSO control alternatives in order to find the CSO plan that best suit the environmental objectives at the least possible cost. Preliminary results show that the proposed CSO plan approach can help reduce the cost of CSO control programs by as much as 30% compared to more traditional approaches.

KEY WORDS: Combined Sewer Overflow, long term CSO control plan, conceptual design, optimal control, nonlinear programming, automatic sewer design, sites of intervention.

1.0 INTRODUCTION

The optimization of a CSO plan is generally a complex task. It demands a broad expertise in various fields including hydrology, hydraulics, environment, mathematics, civil and mechanical engineering, and process control. Difficult issues such as the localization and the sizing of retention facilities, the assessment of additional transport and treatment capacities and the choice of a control strategy have to be addressed and answered, ultimately in an optimization process. Therefore, to decrease the potential risk of designing a CSO plan that is not properly optimized in terms of implementation cost and/or CSO reduction, most engineers use hydrologic and hydraulic simulation tools to perform there CSO plan studies. In general, the approach followed consists of finding the CSO sites, according to a prior knowledge of the sewer network behavior, identify control solutions, and simulate the proposed solutions in order to find to most profitable one in term of CSO reduction and construction cost.

This conventional CSO plan approach is simple and has proven to be valuable over the years in many cases of application. However, the conventional approach precludes the study of all combinations and permutations of a large and diverse solution set since each change is evaluated through a trial and error process. Moreover, most hydrologic and hydraulic softwares used do not have the ability to investigate control outside of static or local control. As a consequence, there is no guarantee that the best CSO plan found using the conventional approach is the best CSO plan that could have been proposed.

In the present paper, a new CSO plan approach is presented. Conversely to the conventional approach, the proposed method breaks the barrior of the trial and error method and enables to evaluate the environmental performance and the implementation cost of a large number of CSO control measures. The approach also evaluates the influence of the selected management strategy on the cost of the best CSO plan that complies with the environmental objectives. The use of the CSO plan optimization method and the software MED-SOM, developed by ASSEAU-BPR, is illustrated through various projects. The work plan described below is the one that will be used for the development of the CSO plan of the Westerly District for the Northeast Ohio Regional Sewer District (Cleveland, Oh).

2.0 CSO PLAN OPTIMIZATION WITHOUT THE CONSTRUCTION OF NEW FACILITIES

Different operating control modes have been proposed in the literature for the management of sewer networks (Papageorgiou, 1988; Gonwa and Novotny, 1993; Gelormino and Ricker, 1994). Just changing the mode of operation of a sewer network from static control to dynamic control can readily maximize the use of existing transport, retention, and treatment capacities. Furthermore, it has been shown, in the example of the Quebec Urban Community CSO control project, that these measures are cost effective compared to the construction of new facilities (Lavalle et al., 1996). Using the MED-SOM software, the CSO performance of three control strategies can be evaluated: static control, local control, and global optimal control. We explain below how these control modes operate using MED-SOM.

2.1 Static control

The static sites of control enables to simulate the sewer network behavior associated to fixed flow regulators such as orifices, weirs, gates, and pumps. This flow operation mode is simulated directly by MED-SOM without any other inputs from other commercial hydrologic and/or hydraulic softwares (e.g., SWMM, HydroWorks). In this case, the commercial models are used only to validate and calibrate the simulations done with MED-SOM. In a long term CSO plan, a plan defined with no new facilities and static control permits to assess the minimal acceptable performance.

2.2 Local dynamic control

Local reactive control enables to maintain a prescribed flow or water level downstream of a flow regulator. This type of control is used to minimize the risk of flooding and to maintain hydraulic stability into the network during rainfall events. Conversely to the static control mode, the locally controlled sites can be designed to maintain a constant flow to the wastewater treatment plant without regards to the hydraulic load found into the sewer network.

In MED-SOM, the water level set points are converted at each control period as flow set points using PID (Proportional Integrative, Derivative) algorithms. All flows and water level set points can be time varying, however, the variations must be defined prior to the beginning of simulations. While the behavior of the network is simulated with the commercial models, the local set points can be defined by the designer or computed by MED-SOM. If computed by MED-SOM, the local set points are such that the total overflow volume is minimal for the rainfall event considered. Therefore, with MED-SOM, the design engineer can determine the best performance, in term of CSO reduction, that can be achieved when using local control.

2.3 Global optimal control

Global optimal control consists of finding, at each control period, the flow set points that enables to achieve specified control objectives. Control objectives can be : the minimization of the CSO volumes, the maximization of the use of the wastewater treatment plant capacity, the minimization of dewatering time, and the minimization of operating costs. Moreover, this control strategy enables to meet specific requirements at each control sites. For example, specific pollution sensitivity can be assigned to overflow sites in order to transfer overflows from more sensitive receiving water bodies to areas that can handle more important pollutant loads.

In MED-SOM, the optimization problem that consists in finding the optimal set points, is solved using a CEOLFC (Certainty Equivalent Open Loop Feedback Control) strategy in conjunction with a nonlinear programming algorithm with linear constraints (Methot and Pleau, 1997; Pleau and al., 1996). The choice of such a problem formulation reduces computing times and improves the robustness of the global optimal strategy in real time control. In particular, the robustness problem associated to modeling uncertainties is addressed by correcting the flows and volumes predicted in the optimization loop according to the flows and volumes simulated by an explicit hydraulic model such as SWMM. The operating and control objectives as well as the constraints defined in MED-SOM are summarized in Table 1.

The future rainfall needed to built the optimization problem can be provided in MED-SOM either by a meteorological forecasting model transforming radar images into future rainfall intensities (e.g., CALAMAR) or by extrapolation routines based on past measurements. In particular, the future rainfall intensities can be extrapolated using a bell shape Gauss curve calibrated on past rainfall measurements.

The behavior of the control sites and flow regulators dynamic can be simulated by MED-SOM to reproduce as closely as possible the behavior of the sewer network. The regulators' dynamic is approximated to a first order model with dead times, whereas the sites are controlled by PID algorithms. The architecture of the global optimal scheme is presented in Figure 1.

The simulation results recorded when all the flow regulators are globally and optimally controlled give a good assessment of the best environmental performance that can be achieved without the addition of new facilities. Therefore, if these results do not meet the environmental objectives, one must include the addition or the replacement of facilities within the CSO plan development.

3.0 CSO PLAN OPTIMIZATION WITH THE CONSTRUCTION OF NEW FACILITIES

In the majority of the CSO plan projects, the environmental objectives cannot be fulfil only by modifying the control strategy, and new facilities have to be built or replaced. MED-SOM can be used to simulate and optimize a predefined set of CSO control solutions, from a more conventional approach. The added benefit of using MED-SOM is in evaluating how these facilities can best be operated, according to one of the operating modes described above. Under this approach, the planned CSO control facilities can be set to fixed capacities or have an initial null capacities. If the capacities are assumed to be zero, the overflow volumes recorded at each retention site can be associated to the retention volume that should be built in order to have no overflows.

MED-SOM also enables to perform automatic CSO plan optimizations with basic information such as control site availability. The approach consists of investigating, in a global optimization problem, all the potential combinations and permutations of CSO control facilities, locations, and sizes, and to find the solution set that meets the environmental objectives at a minimal cost. The construction of the optimization problem is made by defining a fictitious sewer network including at each possible site an infinite number of new retention tanks, conduits, or treatment facilities. Each facility has a capacity ranging from 0 to a maximum capacity – usually related to geometry of the water works and land availability. From this complete network, including all possible CSO control solutions and possible operating modes and with an infinite number of potential facilities, the automatic CSO plan optimization routine finds the best CSO plan that optimally fulfills the environmental objectives specified.

3.1 The cost function

The cost function defined in the automatic CSO plan optimization approach is built according to a table relating costs to retention capacities. The table can be defined by the design engineer or it can be automatically built by MED-SOM using the physical description of the sites. The cost function is represented in the optimization problem as a smooth cubic function guaranteeing the convergence of the CSO plan optimization to an optimum. The parameters of the cubic function are computed using a linear regression routine, such that the sum of the squared difference between the costs defined in the table and those predicted by the smooth function is minimal.

3.2 Designing new facilities

The designing mode implemented in MED-SOM is usually used in the planning process to pre-design the new facilities. In order to use this feature, data related to the geography and the geology of the retention sites have to be defined. The results provided by MED-SOM include various retention tank design information such as: the volume of excavation, the width, the length and the height of the storage tanks, the thickness of the base and the roof, the number and the diameter of the columns needed to support the roof, and the depth of the tanks in the ground. The design informations are determined in conjonction to the cost function to assure the lowest CSO plan cost.

3.3 A case study: the Quebec Urban Community CSO plan project

The west side of the sewer network of the Quebec Urban Community (QUC) is composed of three main interceptors merging at a connecting chamber. Downstream from that point, the flows are conveyed through a tunnel to the wastewater treatment plant. The plant has a capacity varying between 110 MGD and 135 MGD depending upon the St-Lawrence River's tide. The actual storage capacity of the network is provided by two tunnels, the *Affluent Tunnel* upstream of the treatment plant (capacity 4 MG) and the *Versant Sud Tunnel* located in the south interceptor (capacity 0,2 MG) (Figure 2).

The objective of the QUC study was to develop a CSO control plan to reduce the total CSO volume below a prescribed value of 80 MG per summer, taking the summer of 1988 as an average year.

The QUC CSO control program will begin by implementing global optimal predictive control in order to benefit from the existing in-line retention capacity provided by the two tunnels cited above, and the wet weather treatment capacity of the wastewater treatment plant. The 4.6 M$ investment for implementing this first phase of the CSO program is very cost effective. It will help eliminate 60% of CSO events and reduce the total CSO volume by 60% during an average year, as shown by simulation with MED-SOM for year 1988 (Lavalle et al., 1996).

The remainder of the QUC CSO control program for this western portion of its sewer network consist of building four additional retention tanks (sites C,D,E,F) totaling 4 MG of retention capacity. These tanks will also be operated under global predictive real time control for improved performance. Using a conventional control approach the estimated retention volume needed was superior than 5 MG. Therefore, a reduction of 25% in volume needed to comply with the environmental objectives was superior than 5 MG.

3.4 A case study: The central region of Ile-de-France

The sewer network modeled within MED-SOM for the CSO plan study of the central region of Ile-de-France is composed of five interceptors located along the Seine River. The objective of the CSO plan was to find a set of CSO control solution which would help maintain acceptable water quality levels in the Seine and Marne Rivers for rainfall events of recurrence higher than 1 in 10 years.

Seven potential retention sites, including tanks and tunnels were identified from a first screening process aimed at locating the land available for the construction of storage facilities. New transport facilities, allowing the transfer of water from one interceptor to another or from an interceptor to an existing or planned treatment station were also considered as potential interventions. After a second screening process, six transport facilities and five wastewater treatment plants (new or to be upgraded), were included in the CSO plan study.

In this study, four sets of solutions designed to handle 80% of wet weather overflows discharged into the Seine and Marne River for a 1 in 6 months rainfall event, operated under static control. We further analyzed these four scenarios applying global predictive real time control and showed we could improve the environmental performance of all four scenarios by some 30%. This improved performance meant that we could then comply with wet weather water quality objectives for a 1 in 10 years event.

3.5 A case study: The Westerly District in Cleveland

Asseau-BPR has designed a methodology for the elaboration and optimization of the CSO plan for the Westerly District of the greater Cleveland area according to the plan described above:

Assess the potential of applying a single type or a combination of static, local control, and global optimal control to the existing system, maximizing in-line storage, and CSOTF and WWTP capacity.

Add transport capacity to the previous scenario if the existing treatment facility capacity is not attained.

Add new retention facilities within the combined sewer network, if needed.

Add treatment capacity at the wastewater treatment plant or on-line treatment at different points within the network.

Evaluate the benefit of interbasin transfers to the East or South WWTP District.

The location and sizing of the global combination of these facilities will be facilitated by the automatic design capabilities of MED-SOM.

4.0 CONCLUSION

A new CSO plan optimization approach has been presented. The approach integrates the sewer network management rules and all the possible scenarios of intervention that can be planned by the design engineer in a single CSO plan optimization study. As a consequence, a large number of scenarios of intervention can be investigated in a very effective manner, with little resources and in a short period of time. Moreover, since the automatic CSO plan approach is based on nonlinear programming, the scenario of intervention chosen by MED-SOM is guaranteed to be optimal with respect to the objectives specified by the operator. And for robustness, MED-SOM works in parallel to a commercial model (e.g., SWMM or HydroWorks, etc.) to assure a good representation of the hydraulics and the hydrology.

This novel optimization approach has been used in various projects with substantial success: in the Quebec Urban Community, we have been able to show a very significant cost effective first step by applying global optimal real time control and the cost of the complete CSO plan has been reduced considerably; in the central region of Ile-de-France, we have been able to increase the environmental performance by applying real time control to all four set of CSO control solutions previously defined for static control. The automatic plan optimization process will be further applied to the Westerly District of the greater Cleveland area.

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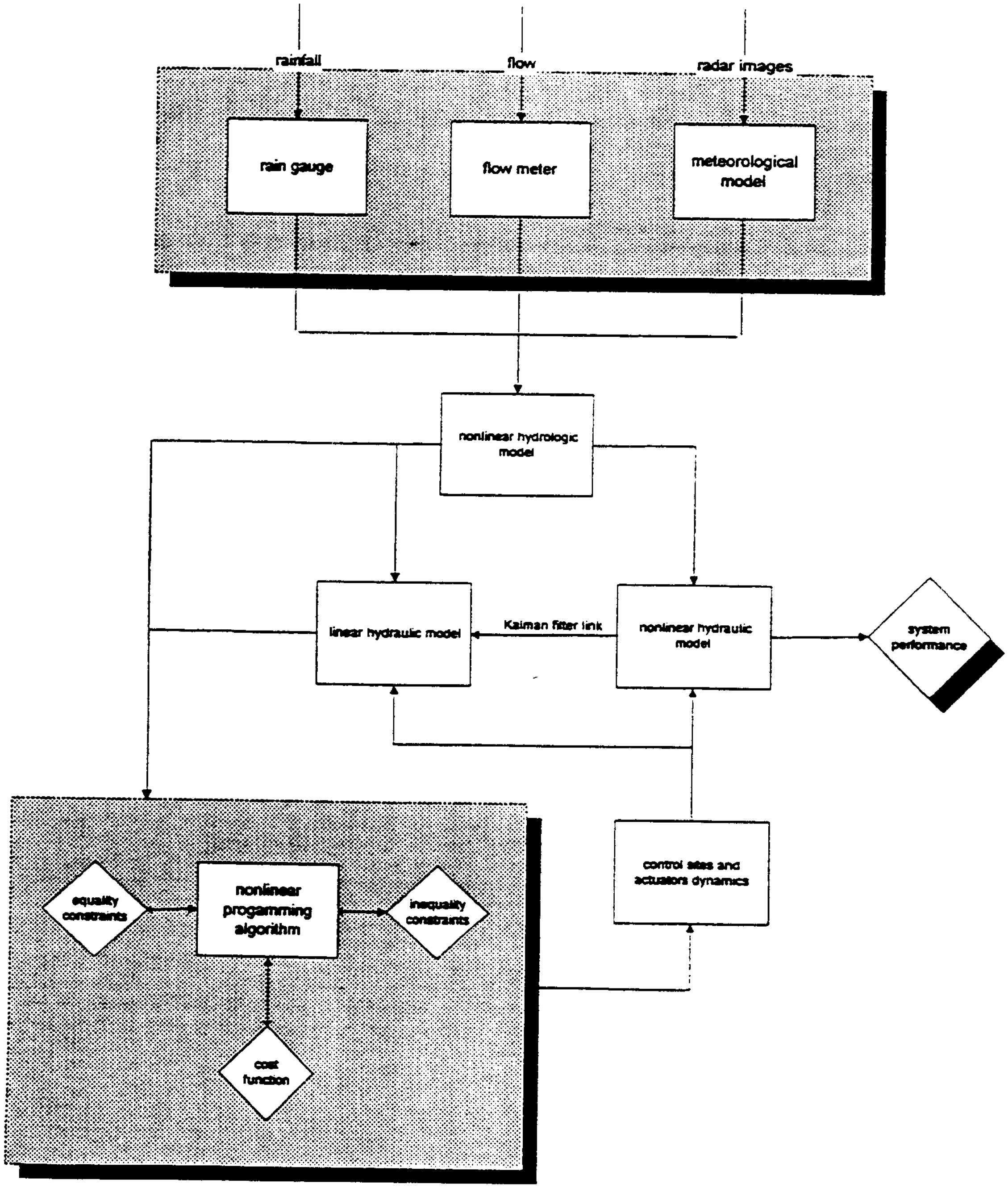
Table 1. **Control objectives and constraints defined in the nonlinear programming problem.**

Control objectives	operating objectives	physical constraints	operating constraints
minimization of the overflow volumes (local and global)	all the flow conveyed to an actuator that is inferior to a fixed set point must be intercepted (local)	continuity equation around the storage facilities (local and global)	the manipulated variables are bounded between zero and a constant (local)
maximization of the wastewater treatment plant capacity (local and global)	no flow exceeding a fixe set point can be intercepted. It must be stored or overflowed (local)	maximal dewatering flow rates imposed by the hydrostatic heads (local)	the storage variables are bounded between zero and the capacity of the storage facility (local)
minimization of the dewatering time (local and global)	at a reservoir for which the overflow location is at the top, no overflow can occur before the reservoir is full (local)		the flow rates at specific pipes are bounded between zero and a constant (local)
inimization of the manipulated flow variations: first and second derivative (global)			the variation of the manipulated variables are upper bounded by a constant : first and second derivative (local)
minimization of the flow exceeding the constraints imposed at specific pipes (local)			
minimization of the flow exceeding the constraints imposed at the wastewater treatment plants (local)			

Figure 1. **The CEOLF control scheme**



R0025356

Figure 2. QUC sewer network

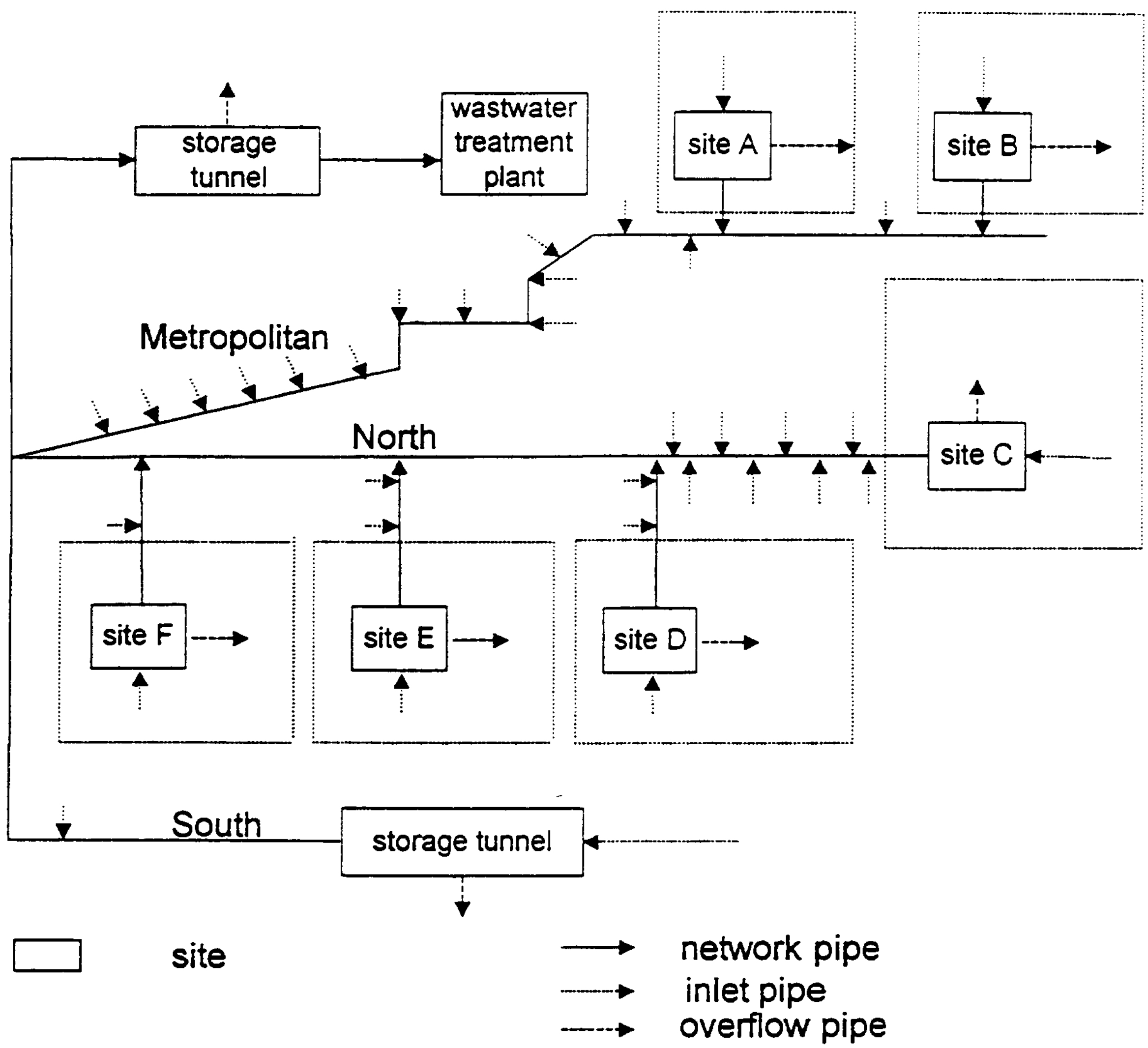


Table 2. **Predicted overflow volumes for the 1988 summer for the West portion of the QUC sewer network**

	Rainfall		Overflow volumes (m^3)	
	Imax10 (mm/h)	Depth (mm)	Static	Dynamic
July 10	61.85	41.76	93770	54049
August 4	59.87	32.83	62250	40222
August 28	44.59	30.62	43900	25787
August 14a	44.59	27.76	55902	34739
August 6	58.44	17.28	35936	15759
July 11	45.60	22.00	38712	27201
July 26	47.86	13.37	27079	14933
August 15	28.34	19.04	27808	9932
August 24	23.47	20.69	20639	4418
July 14b	37.88	10.95	21664	8296
August 26	23.48	16.42	21982	8891
June 22	21.61	14.57	24710	12380
June 28	11.75	20.58	34003	10428
May 16	9.12	20.28	30245	7266
August 13	19.03	9.53	16658	6671
May 23	21.57	7.20	11825	3980
September 4	8.40	17.00	23543	1365
July 30b	18.22	5.69	9377	2281
June 5	10.88	9.19	11186	1053
July 1b	6.83	11.25	13998	2232
June 25	6.68	10.70	13140	786
September 13	7.39	7.02	9472	5
June 30a	10.58	3.44	4305	129
August 10	10.80	2.58	2679	101
total	——	——	722644	292904

EXPERIENCES WITH URBAN STREAM QUALITY MANAGEMENT

(The good, the bad, the ugly, and the promising)

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This presentation will provide a brief review of how our urban streams got into their current predominantly degraded conditions, then summarize activities and results of several recent programs aimed at rehabilitating, or at least protecting, urban streams. As implied by the subtitle, the experiences described in this presentation cover the gamut from successful to futile, with several excursions into interesting. The one thing each of the experiences have in common is that none of the programs and their impacts have proven to be as simple as originally thought.

History provides numerous examples of innovative thinking that oversimplified the problems and consequently contributed to urban stream quality degradation. Roman paved roads with gutters to direct the drainage away from the pathway resulted in simultaneous increases in the flashiness of the drainageway flows, decreases in the vegetative filters bordering the streams, and concentration of the wastes washed off the roads. Thomas Crapper's introduction of the water closet resulted in urban streams becoming the most convenient depository for human wastes. Putting a lid on the drainageways (enclosing the sewers in pipes) protected the public from proximate contact with the noxious contents – and simultaneously removed any remaining habitat in the small urban streams. The River Des Peres in St. Louis, Missouri is a prime example where an urban stream habitat was buried, in that case to clean up the site of the world's fair.

The cholera epidemics of the late 19th century resulted in recognition that the waste carried away in the sewers could still cause problems in downstream water supplies. Chicago's solution to their own pollution of the water supply was direct, expensive, and effective. The sanitary and ship canal diverted the Chicago River away from Lake Michigan and directed the river, and all the sewage from the City, toward the Illinois River. Chicagoans no longer practiced inadvertent re-use of their wastewater, but the Chicago River, the lower Des Plaines River, and the Illinois River became open sewers, subject to low dissolved oxygen, mucky bottoms and noxious algal mats during low flow periods. By the 1920s, Chicago had intercepted the dry weather flows from most of the storm sewers, directing the sewage to a wastewater treatment plant that removed most of the solids and putrecible materials while the urban streams were left with virtually no flow between storm periods. Most inland US cities followed that example and built intercepting sewers and treatment plants in the next few of decades.

The 1972 Clean Water Act started the cities on the path of providing treatment, beyond mere dilution, of their waste waters. However, Clean Water Act strategists continued the trend of oversimplifying the problems. Water quality standards included numeric criteria allowing simple judgement of compliance or non-compliance. Those "simple to judge" criteria resulted in most area wide water quality management plans focusing on the measurable criteria and the recognized point sources. This focus on the simple criteria and the easily recognized sources of pollution resulted in billions of dollars of expenditure. Some streams, like the Cuyahoga River, improved dramatically. Nevertheless, many of our urban streams – like the Cuyahoga -- still fall far short of the quality implied by the Clean Water Act objective of fishable, swimable waters.

Recognition of the remaining problems with our urban waterways has resulted in a number of urban stream protection and rehabilitation efforts. The presentation will summarize several examples. Each will be categorized as good, bad, ugly or promising based on the author's opinion. Recognize, however, that this opinion is based on current understanding of the probable consequences of the programs. History has demonstrated that at no time has the then current understanding proved adequate in the light of hindsight.

Urban stream programs to be summarized will include programs aimed at both dry weather and wet weather problems, such as:

- Chicago's progression from deep tunnels to side stream aeration and suburban stormwater management
- St. Louis Meramec River greenway planning and River Des Peres rehabilitation in
- Stormwater quality management in Santa Clara Valley, California
- Drainage management in Edmonton, Canada
- Watershed management in Montgomery, Alabama
- Watershed management in Atlanta, Georgia

THE URBAN STREAM USE DESIGNATION: A STEP TOWARDS IMPROVED MANAGEMENT

Lester A. Stumpe, P.E., Northeast Ohio Regional Sewer District

ABSTRACT

Urban streams, by definition, have been dramatically altered in ways that have profound impacts on their function and character. Some impacts, like pollutant sources, are directly regulated. However, a host of land use changes are less easily controlled. These include loss of habitat at a wide range of geographic scales, changes of the hydrologic cycle, and direct impacts on streams as a result of engineered structures. In turn these influences trigger a cascade of consequences that further exacerbate stream health. A wide range of constraints in urban areas influences control and restoration efforts. Given these circumstances it is not surprising that urban streams typically do not meet the full range of water quality standards. At the same time, the current usage and/or the potential value of urban waters to a large adjacent population is good reason to seriously consider upgrading the quality of urban streams. These seemingly opposing forces are at the center of the current debate about regulatory use designations for urban waters.

Issues surrounding urban water quality standards and the concept of special urban use designations are explored in the context of facilities planning and ongoing watershed restoration efforts. Specifically, this paper discusses the feasibility of meeting Ohio's bacteria standards for the protection of recreational uses and biological criteria for the protection of aquatic life. It is argued that the unique characteristic of urban problems and the constraints on restoration work in urban area make attainment of existing standards impractical. The development of special urban use designations is suggested as a vehicle for setting reasonable goals in urban areas.
This paper is prepared to prompt discussion at an interactive session at the WEF conference "Advances in Urban Wet Weather Pollution Reduction". Additional data and graphics will be used in the actual presentation.

INTRODUCTION & THESIS

Water quality standards, as a form of a goal statement, should generate a creative discomfort zone that motivates measurable progress to close the gap between the present state and some more desirable state. Time-honored principals of effective goal statements are that they motivate in the intended direction, that progress towards goals can be measured and, finally, that stated goals are achievable. The thesis of this paper is that current standards, as applied to urban streams, are in some cases not achievable and may actually frustrate progress toward restoration.

Urban streams have been severely altered in ways that are, to some extent, irreversible. Still, urban streams can be a substantial community resource if the complex maze of urban constraints can be negotiated. Part of the solution lies in exploring alternative targets for urban streams that benefit urban communities while protecting the larger ecosystem. Without the driving force of realistic targets, restoration of urban watersheds is likely to be a slow and frustrating process.

Given the intractable nature of the urban stream restoration problem, it is appropriate to consider creation of specific urban use designations in place of the current rigid deterministic approach. Thoughtfully constructed, urban use designations could be part of a reinforcement process that helps urban communities to realistically assess the value of urban streams and motivates them to undertake restoration efforts. Elements of the reinforcement cycle would include: The state of the environment ⮝ community understanding of the problem ⮝ water quality goal setting ⮝ corrective actions that address root problems ⮝ state of the environment.

METHODOLOGY - THE MILL CREEK CASE STUDY

Mill Creek drains 11 communities before joining the Cuyahoga River, which in turn is a tributary to Lake Erie. Mill Creek has a drainage area of 60.6 square kilometers (23.4 square miles) with a length of 20 kilometers (12.2 miles). The average stream gradient is 1%. A unique feature of the water course is the 18 meter (60 ft.) waterfall that effectively divides the upper and lower portions of the stream and provides a virtually absolute barrier to fish migration.

Land use in the watershed is primarily urban, zoned for single and multiple family dwellings. A portion, located mostly along main streets, is zoned for retail business, commercial office or industry. Open space is limited to parks, cemeteries, golf courses and a racetrack. Detailed sewer modeling studies identified that the imperviousness for the drainage area is in the range of 35 to 40%.

The drainage system for the area includes separate sewer and combined sewers. A large capital program to construct storage tunnels, interceptors and connecting local sewers to control point source pollutants is currently underway. As a part of the facilities planning process for these facilities, the Northeast Ohio Regional Sewer District (NEORSD) embarked upon an extensive program to study the water quality issues of Mill Creek.

RESULTS/DISCUSSION — AQUATIC USE STANDARDS

- **OHIO'S AQUATIC USE STANDARDS**

Ohio is fortunate to have a mature water quality management program that includes a focus on the end uses of water bodies. In particular, the Ohio Environmental Protection Agency (Ohio EPA) is nationally recognized for having a model program which sets targets for the biological functions of streams.

In brief, the program establishes criteria for benthic macro-invertebrate populations (utilizing the ICI index) and the fish community (utilizing the IBI index) based upon the characteristics of a particular water body. Reference scores, which are specific to eco-regions within the state, form the basis for expected criteria scores. Ohio EPA has developed its Qualitative Habitat Evaluation Index (QHEI) as a tool in helping it to evaluate the habitat characteristics of a particular stream segment. An underlying premise is that there is a strong correlation between QHEI habitat scores and expected IBI scores where the influences of sources of pollution have been eliminated. Mill Creek has been assigned a use designation of Warm Water Habitat, which is Ohio's most common aquatic life use, and the lowest designation that Ohio identifies meeting as the fishable goals of the CWA.

A question that is explored in this paper is whether biological criteria, derived from relatively un-impacted reference streams, should be used as a standard for streams that have predominately urban watersheds. A similar alternative question is whether the QHEI assessment process is adequately sensitive to urban stresses that would preclude the development of a balanced biological community.

- **MILL CREEK STUDY DATA**

Results of habitat evaluations conducted during the study show that the QHEI scores are at the top of the good to fair range. Yet the results of the Mill Creek water quality study show that the benthic community was depressed, as measured by ICI scores. The fish community scored in the very poor range on the IBI scale. These results could indicate that point sources are having a major impact on the aquatic life. However, the depth of data collected in Mill Creek suggested that while water quality is impaired, it is not degraded to a degree that would explain the low biological scores. As a result, the Mill Creek study began to focus on a wide range of other possible contributing influences. This included a geomorphic assessment of the stability of Mill Creek's stream channels. The study team concluded that low fish scores and depressed benthic scores are the result of a complex mix of factors typical of urban watersheds. Control of pollution sources is expected to improve water quality for aquatic life, however habitat loss and hydrologic changes are expected to preclude attainment of aquatic use criteria. A review of the literature on the subject suggests that streams dominated by urban land uses typically are not able to maintain biological integrity. The literature has consistently shown that decreased biological function correlates well with increased levels of imperviousness.

- **DISCUSSION**

Looking at root problem causes — A key to setting realistic expectations for urban streams is to understand the chain of events triggered by the urbanization process. One chain of events starts with the alteration of the hydrologic cycle caused by an increase in the amount of impervious surfaces. Altered hydrology (higher high flows, and lower low flows) can have its own direct effect on the biology of a stream. For example, low flows result in fewer pools and riffles for fish during critical periods. Higher stream flows translate to higher stream velocities, which may stress certain fish species. A secondary impact of the increased frequency of higher flows is the disruption of the stream's natural dynamic equilibrium. In response higher flows channels typically change by widening or down cutting. The resulting bank sediment loads can cause significant stresses to a streams aquatic life. Additionally, the new sediment load can be the trigger for additional channel changes further down stream. Because of ongoing efforts to protect infrastructure by locking the channel into place with various engineered solutions, the channel is prohibited from achieving a natural dynamic equilibrium. A similar analysis can be done for primary actions related to the destruction of habitat and engineered changes within the stream corridor.

The above analysis points to the fact that urban stressors are plentiful and their interactions are complex. Further, many of these stressors are typically not subject to regulation under the Clean Water Act. At least not in a practical and direct fashion. Accordingly, most regulatory requirements continue to be focused on sources of pollutants (typically point sources). This focus can be counter productive if attention is directed from more fundamental root causes of stream impairments.

Urban environments present multiple constraints — Urban stream restoration efforts, including riparian corridor creation, channel re-engineering and soils bio-engineering in combination with hydrologic stormwater management, hold some promise for the restoration of streams. However, these techniques are far from a panacea. In urban settings it is difficult to apply these techniques at the intensity needed to restore streams to levels that can support the diversity of natural occurring ecosystems.

For example, meaningful corridor restoration is likely to involve substantial land use changes. Further, and not surprisingly, the amount of corridor restoration needed is related to the degree of biological integrity that is desired. Creation of a 15 to 25 foot corridor may help substantially in stabilizing stream channels. However, a more comprehensive goal of biological integrity may involve development of corridors 100 to 300 feet in width. In addition to the high cost of land in urban corridors, there are social issues related to individual impacts upon existing landowners.

Re-engineering of channel morphology is often severely constrained by the practical cost of moving extremely expensive infrastructure to achieve desired channel patterns and form. Additionally, stable channels need to be designed to transport rather large channel forming flows and their sediment loads. Channel dimensions and features for these high flows are not likely to match dimensions that are ideal for supporting desired aquatic life forms under conditions of dramatically lessened base flows (a direct result of urbanization).

Theoretically, intensive stormwater management can mitigate some of these problems. For example, storage and controlled discharge can manage peak flows. Infiltration techniques, if broadly enough applied, can lessen peak flows and help restore base flows. But the application of all of these techniques may require allocation of significant land areas and in fact substantially impact upon land use.

Starting with Community Values — These practical impediments are not a reason to given up on urban stream. Urban stream management is in fact an area where interest is growing rapidly. At NEORSD, we promote urban stream restoration believing that we can be part of community efforts to revitalize and, in certain cases, may yield a return in hard economic terms. (For instance a major urban neighborhood redevelopment project is marketing heavily its connection to Mill Creek as an asset.) The key is working with the community to establish goals that make sense at the community levels.

Our experience with watershed planning at the community level shows that urban flooding concerns are often the top priority. A second tier of concerns might include degraded stream esthetics, lack of recreational access, or stream safety. The community does place some value on knowing that a stream is healthy, but in urban areas there is not generally a strong expectation that streams be returned to a near natural biological state. The message from our public is that they support stream enhancements at reasonable costs, where they address understandable problems and where it makes economic sense.

The general public seems willing to accept a varied range of biological integrity for urban streams. However, Ohio's use designation process recognizes few permanent intermediate points between a culverted stream, which is not listed as a water of the State, and the use designation of Warm Water Habitat that is seen as meeting the goals of the Clean Water Act for fishable waters. It is logical to suggest that there should in fact be a range of choices for urban streams, or even a reasonably easy process for community creation of a "designer" use designation.

Minimum biological standards — A strong case can be made for the development of some minimum biological standard. However, minimum standards need to be tailored to account for specific situations. One important argument in favor of biologic criteria is that the biological community serves as a continuos sentinel of chemical water quality conditions. For example, a poor biological metric score, where a good score is expected, could be indicative of a toxic spill. Another argument for biological criteria is that when they are being met, they may constitute proof of ecosystem health not with standing some marginal problem with chemical criteria. In both cases, the key is tying a particular metric score to a reasonable expectation. Because the metric scores that constitute the current standard are derived from sites not predominately impacted by urban conditions, it is reasonable to question if they constitute an achievable goal for altered urban areas.

Unfortunately, the selection of an appropriate reference site is not an easy matter. The ideal sites would seem to be fully urbanized watersheds where point source and nonpoint source controls have been fully implemented. While degraded biological communities are common in urban areas, many of these streams have yet to benefit from the full implementation of technology based controls. Additionally, the degree of urbanization of a watershed should logically be a factor in setting minimum goals. Still another difficulty is recognizing the impact of a range of different geological conditions. For example, the stability of streams can be expected to be influenced by valley profile and soil types the degree of hydrologic disturbance, etc. Fortunately, it may be possible to account for a range of geological variables through by use of stream classification schemes. Classification schemes group the responses of stream to multiple variables into a limited number of stream types. Specifically, it may be possible to develop minimum biological metric that explicitly account for habitat, and stream type.

Beyond minimum standards — Some urban area will want to consider restoration beyond a minimum level. But what levels of restoration are achievable? What are the costs? Which restoration techniques and which best management practices work for specific circumstances? State environmental protection agencies have the expertise and data gathering capabilities to help answer some of these questions for communities who can be motivated to go beyond the minimum. Additionally, these data sets would be valuable to communities who are considering urbanization. At the current time we do not have a full range of tools to help urbanizing communities understand the impact of their land use plans on streams. Additionally, where urbanization is chosen we need tools to help communities quantitatively understand what measures can be taken to mitigate the impacts. For example, what is the value to a stream of establishing a given corridor width for a certain percentage of the stream.

Finally, cause-effects data would be valuable for future comprehensive watershed trading. One of the constraints on tailoring use designations to urban areas is the need to consider the impacts on a larger ecosystem scale. For example urban water quality may be significantly impacting a down stream resource. It is likely that these situations will have to be handled on a case by case basis. Also, because the cost of environmental protection can be very substantial it may be appropriate to call upon the market place to help make decisions about how and where such protection can most efficiently be provided. For this type of market driven watershed trading to occur it would be desirable to have better data on the impacts of urbanization and the most cost effective restoration techniques.

In summary, biological indices can be valuable in tracking progress of urban stream restoration efforts. While urban biological metrics are typically low, improvements can be made through the application of evolving stream restoration techniques. Depending upon the degree of urbanization and the constraints that exist, major aquatic life improvements may be quite expensive. The key to choosing an appropriate stream target is to involve the community in the goal setting process. However, the current states of engineering and science do not allow for a deterministic approach to stream restoration. Progress is generally made through incremental approaches and these typically involve learning from errors and building upon the successes of previous efforts. Logical scientific reasoning and practical aspects of dealing with urban constraints suggest against regulatory standards based upon reference reaches with little urban impacts. A case can be made for the development of minimum bio-criteria based upon urban reference streams. Additionally, a database on the restorative effects of stream restoration practices would be valuable to communities who are considering voluntary efforts to restore streams, or are in the process of making land use decisions.

RESULTS/DISCUSSION — RECREATIONAL USE STANDARDS

- **RECREATIONAL USE DESIGNATIONS AND CRITERIA**

Use designations for recreational use in Ohio are based on the physical depth of the water body and the type of use anticipated. The "Primary Contact" use designation is assigned to any water body of sufficient size to allow for the possibility of full body contact. Ohio's bacterial criteria for recreational use, as is common in other states, are based on the concept of indicator organisms. Fecal coliform and E. coli are assumed to correlate with the presence of pathogens which can be transmitted to, and cause illness in, individuals which come into contact with the contaminated water. Ohio's recreational use criteria are shown in Table 1.

- **MILL CREEK STUDY DATA**

Extensive quality and quantity modeling was undertaken to assist in sizing a system of storage tunnels and conveyance interceptors for combined and separate sanitary sewers in the Mill Creek drainage area. Using source data in combination with conveyance models and water quality models, facilities planning studies develop tools to show the positive impact of the controls. Current condition continuous model runs show that during events that produces significant run off bacteria concentrations will rise very quickly to levels in the range of 500,000 bacteria counts per 100 milliliters. Generally with in a period of 24 hours, the stream will have flush out high bacteria concentration and return to typical back ground levels. Model runs show that the $180 million capital improvements program will substantially reduce the peak bacterial concentrations to levels in the range of the 50,000 counts per 100 milliliter. However, the duration of stream bacteria concentrations which exceed the standard level of 2000 counts per 100 milliliter does not change substantially. These results reflect the fact that the bacteria concentration of stormwater is expected to remain high even after reasonable measures to repair the area sewer infrastructure.

- **DISCUSSION**

Urban environments are severely altered— As discussed in the preceding section, even after a very expensive program of capital improvements, Mill Creek is not expected to comply with recreational use standards. Similar situations are common for urban areas across the country. To understand this problem, it is useful to begin the discussion of appropriate goals/standards for recreational use by analyzing the factors of urbanization, which contribute to the bacteria problem.

By definition, urbanization creates a density of population that will characteristically be served by a system of sewers. Older sewer systems where characteristically designed with relief points (i.e. combines and separate sanitary sewer overflow points). With large expenditures these sources of pollution can be controlled to an extent that they are no longer a dominant factor. Still, this leaves a large underground wastewater sewer net work which represent a potential source of contamination. Theoretically, collection systems could be designed and maintained for zero discharge of pollutants. However, in practice every manhole and every pipe joint (including those of private laterals) is a likely source of pollution during some part of its life cycle.

The other major source of pollution is the direct run off of bacteria from land surfaces. In pre-development conditions the largest fraction of this load would not make its way to streams. Through the process of filtration either (e.g. through soils or through the forest litter) much of the bacteria load would be filtered out. However, in the urban environment, it is only a very short path (typically across pavement) for surface bacteria to be washed into a storm sewer inlet for a subsequent quick ride to a stream.

Typical standards may not consider the special circumstances of urban dominated streams —
The construction of Ohio's recreational use standards is typical of the approach use by other states (i.e. setting a requirement for the geometric mean of five samples in thirty days and allowing a percentage of points to exceed a second higher limit point). Standards constructed in this manner should be able to pick up long term sources of contamination and yet not record an undue number of positives. In beach situations, for which standards were probably first constructed, there is also generally a large body of water that dampens contaminant variability. However, as discussed earlier, urban dominated streams characteristically experience a quick rise in bacteria concentrations in connection with rain events. The fall of bacteria concentrations in urban dominated steams is also relatively quick when compared with bacteria decrease for event contamination at beaches. Given this variability it seems unlikely that current standards are the best possible tools for protecting public health or measuring progress.

Looking at results of stream modeling before or after implementation of controls it is fairly easy to determine wet weather periods when recreational contract should be discouraged. However, whether water quality standard calculations will identify bacteria concentrations as a problem depends on the chance matching of sampling times with periods that correspond with rain events.

Restoration efforts are constrained — In urban area limited space, cost, individual property rights, and other environmental goals team up to present tremendous obstacles to wet weather bacteria controls. Irrespective of water quality standards it is the hope of most urban area to substantially upgrade their underground infrastructure. But cost practicality, translated to political reality, dictates that current collection systems will not be replaced in mass to eliminate the multitude of potential sources that a collection system represents. Implementation of large regional stormwater storage and treatment facilities is constrained by both space considerations and cost. Further, tunnel storage and treatment as practical necessity where land is not available, may not be compatible with attempts to restore base flows for aquatic life uses. Given these constraints, and the ubiquitous nature of bacterial sources, it is not surprising that many water quality managers in urban areas are rather blunt in stating that safe bacteriological levels are not possible to achieve during wet weather flows for urban streams.

Using positive goal setting as a model — Viewed outside the framework of a regulatory/enforcement model it is fairly obvious that many recreational use standards funk the test of having positive motivational aspects for officials who are charged with achieving them. Standards are imposed externally, at levels that are seen as unattainable. The real community concerns of cost are discounted by the Clean Water Act. And measurement of progress in controlling pollution is often frustrated by the construction of the standard itself.

In fact, urban communities do want safer waters. But given the constraints many would rather aim for more realistic targets. Most urban areas seem to accept the proposition that for the foreseeable future urban streams will have higher then safe bacteria levels following rain events. A logical management option is to discourage contact recreation of urban streams following rain events. In fact this management approach may be prudent for at least two other reasons. First, even with the most sophisticated controls imaginable in place, urban streams will always have a high potential to be contaminated. And second, the hydraulics and unique structures typical of urban streams create multiple safety hazards during high stream flows.

Suggested guidelines — Given the difficulty of controlling wet weather bacteria contamination in urban stream, a better approach may be to focus on management of contact recreation. The following ideas are offered as practical regulatory approach for urban dominated streams.

Establish a use designation, with appropriate criteria, that are specific to dry weather periods. Other requirements, as presented below, could be tied to this use designation; however, the key concept is to tailor programs to community concerns:

- Dry weather monitoring frequency appropriate for the task of quickly finding and correcting dry weather discharge problems.
- Development of tools to help refine the predictability of periods when urban streams are not safe for contact recreation. This would likely include wet weather studies and modeling.
- Development of programs to educate the public about limits of the use designation (i.e. when stream are not safe for recreational contact).

- Implementation of technology based best management practices evaluated against specific targets such as increasing the number of safe contact recreation day's and/ or to decrease the peak concentrations of water borne disease indicators.

URBAN USE DESIGNATIONS — STARTING A CONTINUOUS IMPROVEMENT CYCLE

The Clean Water Act is rightfully recognized as one of this countries best piece of environmental legislation. Fairly inflexible standards have, in fact, worked to bring about improvements that were long overdue. For instance, the CWA was successful in combining incentives with the requirement for a uniform level of secondary treatment at municipal waste treatment facilities. More recently, progress has been advanced by consistent water quality standards. Progress continues to be made in using the science of ecosystem assessment to define water quality problems and to identify needed reductions of pollution sources. However, it is also clear that these improvements are in areas in which the CWA has clear regulatory authority. Further, progress has been achieved by setting goals at reasonable levels. Restoration of urban dominated streams present unique challenges which do not appear to have yielded well to the top down standards approach. A viable model for restoration may start with acceptance that the Clean Water Act is not the best approach to control land use decisions related to urbanization.

The suggested starting point for an alternative approach to restoration is a fundamental evaluation of the problems and cause of urban stream impairments. With this information in hand the community can be involved in setting goals to drive corrective actions that will strike at root problems. Goals should be achievable, measurable and be in line with community values. This model de-emphasizes the focus on defining the end point, in favor of efforts to promote continuous improvement. The reinforcing aspects can be represented by a causal-loop with the following elements: state of the environment ^ community understanding of the problem ^ water quality goal setting ^ corrective actions that address root problems ^ state of the environment.

To continue to focus on standard setting at the state level to provide direction to the restoration of urban streams may actually frustrate a more productive continuous improvement model. Consider how externally imposed standard can impact the various elements of the proposed reinforcement loop. For example, current standards do little to provide the basic incentive for an urban community to look fundamentally at the full range of causes for impairment of urban stream. Instead, standards have focused our attention on pollution abatement. Too often a meaningful goal setting process is never started, because externally imposed standards are already set at unachievable levels. We are required to proceed with expensive controls designed to achieve compliance with pollution reduction standards. But could this money have been better spent on selected restoration technologies that deal more fundamentally with the root problems and produce results that are more valued by the community? The answer to this last question affects the likely hood that the community will feel positive about its expenditures and will be willing to become critically involved in discussions about the next step of an improvement process.

In contrast, the development of a specific urban use designation could actually be the catalyst for community work to fundamentally define the root problems that are at the heart of urban stream impairments. If flexibility is allowed in setting goals the community can respond with ideas that are efficient in increasing the value of the resource. In fact these corrective actions may start to target the root causes of urban stream with measures such as habitat protection or restoration. With the support of data from state environment agencies, communities might have access to information that could affect choices about stream restoration or land use. Minimum standard could still be set as needed to protect down stream resources or to provide needed leverage against particular sources of pollution. Ownership in a goal, set at the local level, is likely to encourage the concept of individual stream stewardship and individual action at the homeowner level. Whether dramatic changes occur quickly should not the appropriate measure of success for the model. A more important measure is whether the community is engage in a process of discussion about protection and use of the resource.

CONCLUSION

Urban streams and their immediately adjacent corridors have typically suffered a range of virtually irreversible direct impacts. (For example, all first order tributaries of a stream may in fact be storm sewers.) Given these dramatic changes it is unrealistic to expect urban streams to achieve standards that are attainable in less impacted areas. Further, the numerous physical and practical constraints in urban areas limit what can practically be accomplished through stream restoration techniques. Large gaps between the requirements of standards and what is practically achievable in an urban setting can actually result in a counter productive situation.

Too frequently urban water quality is treated as an all or nothing proposition (e.g. either an urban stream is treated as a sewer that is not a regulated water body or it is expected to be upgraded to meet full fishable and swimmable criteria.) Minimum standards are appropriate. However, these standards should in fact be minimum standards and should recognize that in some cases irreversible changes have taken place, which are not regulated by the Clean Water Act.

Given the intractable nature of many urban water quality problems it is appropriate to rethink both the targets set by standards and more fundamentally the role of standards. Urban use designations offers a way to solve problems by focusing special attention on the particular problem causes and constraints of an urban areas.

The elements which have been suggested are characteristically described as the watershed approach (i.e. addressing root problem causes and real world solution constraint, involvement of stakeholders in goal setting, setting priorities to coordination action on the restoration and/or protection of end uses, and principals of adaptive management to take advantage of opportunities). Watershed approach is being accepted as the preferred process for dealing with complex and intractable water quality problems. Few watershed texts would suggest the current process of holding stakeholders to unrealistic externally imposed standards as a way of pressuring stakeholders for progress.

Table 1 RECREATIONAL WATER QUALITY CRITERIA			
Water Quality Criteria:	**Secondary Contact** **Wading**	**Primary Contact** **Full Body Immersion**	**Bathing Waters** **Bathhouse/ Lifeguard**
Fecal Coliform	BACTERIAL COLONIES/100 ML SAMPLE		
Geometric mean of at least 5 samples within 30 days:	No Criteria	**< 1000**	< 200
Maximum for 10% or more of samples within 30 days:	< 5000	**< 2000**	< 400
E. Coli	BACTERIAL COLONIES/100 ML SAMPLE		
Geometric mean of at least 5 samples within 30 days:	No Criteria	**< 126**	< 126
Maximum for 10% or more of samples within 30 days:	< 576	**< 235**	< 235

Assessing the Condition and Status of Aquatic Life Designated Uses in Urban and Suburban Watersheds Using Biological Assessments

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Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biological surveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices for nonpoint sources. Biological criteria are one of the principal assessment tools by which the status of water bodies is determined in Ohio. The results of biological monitoring in selected urban Ohio watersheds shows a tendency towards lower biological index scores with an increasing degree of urbanization and allied stressors, becoming more severe as other impact types such as combined sewer overflows (CSOs) and industrial sources coincide. Out of 110 sampling sites examined statewide, only 23% exhibited good, very good, or exceptional biological index scores. Of the sites classified as being impacted by urban sources, only two sites (4.5%) attained the applicable biological criteria. Poor or very poor scores occurred at the majority of the urban impacted sites (85%). More than 40% of sites affected by suburban development were impaired with many reflecting the impact of housing and commercial land uses. The results demonstrate the degree of degradation which exists in most small urban Ohio watersheds and the difficulties involved in dealing with these multiple and diffuse sources of stress. In the Cuyahoga River basin, which contains older and extensively urbanized subbasins, aquatic life use impairment occurred in the vicinity of 10-20% urban land use. These results contrasted somewhat from a similar analysis of small streams in the Columbus metropolitan area where full attainment of uses was observed at higher proportions of urban land use. In both areas the utility of biological criteria to serve as a reliable and consistent vector for urban land use indicators was demonstrated. Well designed biological surveys using standardized methods and calibrated indicators can contribute essential information to urban watershed management. Because the resident biota respond to and integrate all of the various factors that affect a watershed, their condition is the cumulative result of all significant stressors within watersheds. It is important that ambient monitoring not only be done as part of the overall urban nonpoint source management process, but that it is done correctly in terms of timing, methods, and design.

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WATER QUALITY CONCERNS AND REGULATORY CONTROLS FOR NONSTORM WATER DISCHARGES TO STORM DRAINS

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WATER QUALITY CONCERNS AND REGULATORY CONTROLS FOR NONSTORM WATER DISCHARGES TO STORM DRAINS[1]

L. Donald Duke and Molly M. Kihara[2]

ABSTRACT: Nonstorm water discharges to municipal separate storm sewer systems (MS4s) are notable for spatial and temporal variability in volume, pollutant type, pollutant concentration, and activity of origin. The objective of this paper was to determine whether current technical knowledge and existing U.S. policy support an improved regulatory approach. The proposed policy would use type of discharge as a regulatory basis, merging the concepts of allowability of *de minimis* discharges and type-based statewide consistent rules. Specific research objectives were to comprehensively identify discharge types, characterize their prevalence in California, analyze relevant local and regional regulatory guidelines, and systematically evaluate opinions of experts about potential water quality impacts. Results demonstrate nonstorm water discharges were widespread in at least one sector, industrial facilities subject to a state permit; one discharge for every four facilities was reported in 1995, even though the permit explicitly prohibits such discharges. Clear consensus exists for minimal water quality concern for some discharge types when considering both municipal guidelines and experts' opinions. In particular, condensate from a wide range of equipment and discharges from fire fighting equipment testing were found to be of low concern. Discharge types with consensus high concern were largely limited to discharges prohibited under other regulations, such as wastewater and hazardous waste management controls. Some discharge types where no consensus was identified, such as landscape irrigation, nevertheless generated concern for water quality impacts and appear to be relatively widespread. Available information supports technical feasibility of the proposed policy because at least some discharge types show strong consensus for de minimis impacts among regulatory guidelines and opinions of technical experts.
(KEY TERMS: storm water management; nonpoint source pollution; separate storm sewers; watershed management; urban runoff.)

INTRODUCTION

The Federal Water Pollution Control Act (commonly referred to as the Clean Water Act, or CWA) has evolved from 1972 to the present, incrementally addressing additional categories of discharges, including nonpoint sources and developing different bases for pollutant control. In 1972, Congress established the National Pollutant Discharge Elimination System (NPDES) permit program and mandated the imposition of uniform, technology based limits on industrial and wastewater treatment plant discharges. The Water Quality Act (WQA) of 1987 amended the CWA, imposing water quality based requirements on discharges of toxic pollutants, and adding the control of pollutants in storm water runoff as a national goal.

The WQA explicitly defined storm water discharges as point sources, therefore subject to NPDES regulations. Subsequent regulations required NPDES permits be held by municipal agencies operating municipal separate storm sewer systems (MS4s) serving 100,000 or more people. MS4s are widely found in the western United States, where sharp seasonal precipitation patterns have led flood control agencies to construct systems to convey large peak runoff volumes directly to receiving waters. MS4s discharge all flows directly to receiving waters, even small volume low flows including nonstorm water discharges during dry seasons. This approach is less often applied in the eastern United States, where urban runoff more commonly is conveyed in combined systems, so that low flows are routed through publicly owned treatment works along with sanitary and industrial discharges, and large storm flows may

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R0025375

bypass treatment facilities. The WQA storm water provisions require operators of MS4s to control pollutants upstream of input to the MS4, an approach that avoids the prohibitive costs of centralized treatment for seasonal high volumes of urban runoff.

By regulation, municipal NPDES storm water permits must "effectively prohibit" nonstorm water discharges into the MS4 (40 CFR 122.42), and MS4 operators must implement and enforce illicit discharge elimination programs (USEPA, 1990). The policy is driven by the observation that nonstorm water discharges contribute a potentially significant fraction of pollutants discharged by MS4s to surface waters in certain urban watersheds (Line *et al.*, 1996).

The observation is supported by a limited number of watershed-specific studies. Montoya (1987) determined nearly half the annual MS4 flow volume in Sacramento, California could not be attributed to precipitation. Pitt and McLean (1986) concluded dry weather flows accounted for more than half of annual mass loadings of certain chemical parameters from two catchments in Toronto, Ontario, during 1984. A study of Santa Monica Bay, California, identified significant contributions of metals and other pollutants from dry season discharges (Lau *et al.*, 1994). These results are highly dependent on land uses and other factors in the watersheds. USEPA, in proposing its Phase II NPDES storm water regulations, concluded that nonstorm water discharges contribute a wide range of pollutants such as pathogens, metals, nutrients, oil and grease, and phenols to MS4s across the U.S. (USEPA, 1995). That study's conclusions are based on diverse evidence from inspections, end-of-pipe observations, investigation of sediments in storm sewers, citizen reports, dye testing, dry weather sampling, and fecal coliform tests.

Existing evidence is not sufficiently systematic or well defined to support general conclusions about water quality impacts from nonstorm water discharges to MS4s (Duke *et al.*, 1997). Reliable anecdotal evidence, such as a detailed study of nonstorm water discharges from industrial facilities of the Lawrence Livermore National Laboratory (Mathews and Welsh, 1995), supports the premise that at least some discharges are unlikely to cause water quality problems. However, water conveyed in MS4s is highly variable in frequency, volume, and pollutant concentrations. Therefore, it is difficult to characterize chemical composition of specific discharges or classes of discharges, and to estimate their contributions to pollutant loadings to ultimate receiving waters. Constituent concentration data from sampling and analysis of individual, facility specific nonstorm water discharges to MS4s are not generally found in the primary literature.

Research Objectives

The overall goal was to evaluate water quality implications of types of nonstorm water discharges to MS4s using formal data, indirect evidence in the form of regulatory data, and informal knowledge of experienced practitioners. The purpose was to assess feasibility of a statewide policy to allow selected discharges based on discharge type, incorporating the concept of *de minimis* discharges to be consistent with federal requirements for effective prohibition of nonstorm water discharges to MS4s. The research included three specific objectives. The first was to evaluate current U.S. policy structure to assess the conceptual feasibility of the proposed policy, and use results of the data analysis to assess its technical feasibility. The second was to characterize existing information about types of such discharges widely found in the U.S., in particular in California. The third was to evaluate the current state of knowledge about water quality impacts of such discharges by type.

METHODOLOGY

First, the existing U.S. policy and regulatory structure was evaluated to determine the basis for the proposed new policy. The research then constructed a basic characterization of nonstorm water discharges currently found in California, using the literature to develop a comprehensive list of discharge types and using data collected by state agencies to estimate relative predominance of discharges from one sector – industrial facilities. The authors then evaluated two forms of qualitative information about the current understanding of water quality impacts of nonstorm water discharges, categorically by discharge type. The information evaluated included guidelines now in place for a number of large municipal agencies in California and opinions of a sample of experts from regulatory agencies, the regulated community, and other professionals with expertise in water quality of discharges to MS4s.

Discharge Types

By reviewing the academic literature, descriptive reports by federal and state environmental agencies, and current regulatory guidelines promulgated by federal, state, and local agencies (USEPA, 1990, 1991, 1995; CSWRCB, 1995, 1997), 110 discharge types were identified. The discharge types were organized

R0025376

into 20 categories, but otherwise were accepted largely as found in the literature.

Industrial Discharges

The research evaluated nonstorm water discharges in annual reports submitted by industrial facilities covered under the statewide NPDES General Permit for Discharges of Storm Water Associated with Industrial Activities, or General Industrial Permit (California State Water Resources Control Board, 1997). The analysis established, for one sector of storm water dischargers, whether individual discharges are widespread and which discharge types are most common. To the authors' knowledge, no comparable information is available for discharges from other sectors. This does not imply the industrial sector is necessarily the most important in terms of volume, frequency, or pollutants conveyed in nonstorm water discharges.

The present research summarized that information for five of the nine California administrative regions known as Regional Water Quality Control Board jurisdictions, or RWQCBs. The five RWQCBs selected include some of the most heavily developed urban areas in the state, and are sufficiently geographically distributed to capture potential regional diversity. RWQCB information was acquired under a statewide review project, as described in Duke *et al.* (1997).

Municipal Agency Guidelines

The research next evaluated guidelines from five agencies with storm water pollution control responsibility for large municipalities in California. Guidelines evaluated included regulations or policies targeted at discharge types, and intended to categorically prohibit, allow, or allow under certain conditions discharges of those types to each agency's MS4. The five selected municipalities were known to be among the most active in the state in developing and implementing storm water pollution controls under their municipal NPDES storm water permits. Description of the procedures for evaluating agency guidelines and text descriptions of some of the key agency policies appear in Duke *et al.* (1997), and are not repeated here.

Preferences reflected in existing guidelines may be interpreted as evidence of concern by those agencies with potential water quality impacts of nonstorm water discharges. Those concerns may be considered to reflect current professional judgment about those discharge types which categorically are expected to be detrimental to receiving water quality.

Broad Based Survey of California Experts

A questionnaire was administered to professionals in California with expertise in storm water quality. The purpose of the survey was to characterize current understanding of concerns with potential water quality impacts of discharges by discharge type, and determine whether current opinions approach consensus for any discharge types. Results were compared with agency guidelines evaluated as described above. If local agency guidelines were consistent with one another within discharge types, and also emphasized controls consistent with water quality concerns of experts statewide by discharge type, we might suggest current understanding of water quality impacts is sufficient to support statewide policies. For discharge types where agreement was strong, results support selection of those types as candidates for statewide policies.

Details of the structured survey mechanism are available in Duke *et al.* (1997), and are summarized here. The questionnaire asked participants to indicate, on a simple numerical scale, their degree of concern with each of the 110 discharge types. "Concern" for water quality impacts was defined to include issues of "volume, concentration, and types of pollutants" for each discharge type, as in USEPA's definition of *de minimis* water quality problems (USEPA, 1991). Responses were expected to capture a range of opinions depending on the respondents' depth and type of experience; on their professional interests, such as differing views held by regulators and the regulated community; and on regional factors. The questionnaire instructed respondents to base their answers on concerns for their own MS4, so the responses may depend on the relative prevalence of each discharge type in their region; on characteristics of regional receiving waters, such as susceptibility to certain types of pollutants; and on characteristics of other discharges in the region, with consideration of cumulative impacts of certain pollutants.

The responses were not specific about causes for concerns because the compound question allowed multiple possible reasons for a given score. Further, the results should not be interpreted as type based scores to rank discharge types from greatest to least concern statewide because responses were designed to reflect concerns of a given region rather than opinions about discharge types' importance on a statewide scale. This survey design supported the assessment of statewide consensus by seeking any diversity of opinions on the basis of regional experiences.

For similar reasons, survey respondents were not selected with an intent to be a representative sample of all stakeholders or of any specified group, but

R0025377

rather as a convenience sample of persons with recognized expertise in the field. The sample was developed from participants in the California Storm Water Quality Task Force (SWQTF), a public interest group with advisory status to the California State Water Resources Control Board. SWQTF attendance is voluntary, so no formal membership rolls are maintained, but consistent attendees consist largely of high level staff of municipal agencies operating MS4s that hold municipal NPDES permits for storm water discharges. Other attendees represent regulated industrial firms and their trade associations, public interest groups with broad-based environmental concerns, and public agencies with responsibilities for storm water regulatory development and enforcement. SWQTF attendees were an appropriate source for opinions about water quality impacts of discharges to MS4s by virtue of long experience, responsibility for decisions about storm water pollutants, and a history of active and thoughtful involvement in related policies. Since the purpose was to identify areas of consensus, the convenience sample was considered adequate if it included respondents representing many of California's diverse regions and various professional interests.

The questionnaire was presented at a regularly scheduled meeting of the SWQTF on March 8, 1996. Questionnaires were completed and returned by 32 respondents, with composition as follows: 17 municipal agency personnel; eight industrial personnel; three state or federal regulatory agency personnel; and four consultants, with experience working with all three above groups. Geographically, respondents held responsibilities within four regions of intensive urban development in California. Seven were from Los Angeles and the immediately surrounding region (total 1995 population about 9.1 million); 13 from other Southern California urban regions, from Orange County in the north to San Diego in the south (about 8.2 million); six from the San Francisco Bay Area (about 5.1 million); and three from the Central Valley, from Sacramento in the north to Bakersfield in the south (about 3.9 million). Three of the respondents had statewide responsibilities. Together, the represented regions contained a population of about 26.3 million persons in 1995, more than 80 percent of the statewide total of about 31.6 million.

In evaluating responses, discharge types were considered to have consensus minimal impact if at least 50 percent of respondents selected "1" (minimal) as their degree of concern, and no more than two respondents selected either "4" (moderately high) or "5" (high). Discharge types were judged to achieve consensus high concern if the sum of respondents selecting scores of 4 and 5 represented at least 50 percent of returned questionnaires. This criterion was less stringent than the consensus minimal concern criterion, on the grounds that moderately high concern might be reason enough to justify protecting receiving waters from the discharge.

In-Depth Survey of Selected Experts

Detailed analysis of experts' opinions, the rationale behind those opinions, and the precise nature of their concerns with water quality by discharge type was beyond the scope of the present research. However, a possible approach for detailed analysis was demonstrated by administering a more in-depth questionnaire addressing a small number of discharge types to a small number of selected experts. Results illustrate the types of rationale used by the experts to arrive at their overall condition; the aspects of discharge types leading to high concern, where present; and the definitiveness or tentativity of the current state of knowledge, represented by respondents' stated confidence in their ability to reach conclusions requested.

Fifteen experts were selected from among regular SWQTF attendees recognized to have long experience with storm water quality, high level responsibility with an agency or corporation, and high respect among their SWQTF peers. Twelve of the 15 responded to the request for information. Four had responsibility in the San Francisco Bay Area; three each in the Central Valley and the greater Los Angeles area; and two in other parts of southern California. The experts were drawn primarily from the ranks of municipal agency personnel, but respondents included two regulatory personnel and one operator of a large industrial facility.

Ten discharge types were included in the questionnaire, selected arbitrarily from the list of 110 used in the overall survey. Some of the discharge types were drawn from those where the overall survey showed consensus, either toward minimal impact or high impact. These were selected to verify consistency of the small group with the larger sample and to identify rationale behind those judgments. Others were chosen from types that did not achieve consensus. These were intended to assess consistency of the rationale behind the varying opinions, and also to identify underlying technical factors in the opinions.

RESULTS AND DISCUSSION

Results are organized as follows. The first section below presents the regulatory and policy foundations for control of pollutants in nonstorm water discharges. The next section assesses the degree to which these discharges are widespread in California, through data about the relative frequency with which industrial facilities reported various discharge types in their annual report under the statewide General Industrial Permit. The following section evaluates the current understanding about water quality concerns by discharge types, including results of the expert opinion survey and analysis of municipal control policies. That section is divided into three subsections according to degree of consensus of the opinion survey. The final section discusses findings of the in-depth survey.

Regulatory Structure, Policy, and Basis for a New Approach

The choice between prohibiting all nonstorm water discharges and allowing certain discharges depending on conditions is an example of the choice between "global" and "local" environmental regulations, a recurring theme in surface water pollution control policies in the U.S. Both have significant advantages.

Global regulation specifies uniform requirements for all discharges of a given type, or emissions from a given activity, within a large jurisdiction. Requirements take no account of local or site-specific conditions. The stated rationale for such global regulations is to facilitate enforcement, as it is unnecessary to work backward from an over polluted body of water to determine which point sources are responsible and which must be abated (EPA v. California ex re. SWRCB, 426 US 200, 204, 1976 in Percival *et al.*, 1992). Requirements of the original CWA were global in nature: NPDES rules for wastewater discharges specified technology-based, numerical effluent limits that were uniform by industrial sector. Outright prohibition of nonstorm water discharges to MS4s in California would be a global environmental control policy.

A local approach has the alternative advantage that regulatory requirements can reflect different needs of specific receiving waters depending on factors such as their sensitivity to pollutants, assimilative capacity, and pre-existing degree of degradation. The local approach can avoid inefficient regulating of pollutants or activities not found to be causing harmful effects in a given locale. Agencies can focus regulatory resources on those pollutants, and polluting activities, found to be responsible for impairment of particular receiving waters. Watershed based regulations and discharge standards based on Total Maximum Daily Load (TMDL) calculations are examples of local policies.

USEPA has interpreted WQA's language specifying "effective prohibition" to require that nonstorm water discharges either be directed to sanitary sewer systems or be individually issued NPDES permits for discharge to MS4s (USEPA, 1990). This interpretation allows, within appropriate limits, discharges to MS4s that do not present water quality problems in receiving waters. This approach could achieve some of the advantages of a local environmental control policy. Allowing some discharges can avoid costly and burdensome requirements on the regulated community by permitting storm drain systems to receive nonstorm water discharges which are not expected to convey pollutants that contribute to water quality problems. These discharges include, for example, certain cooling water that does not contact pollutants on commercial or industrial surfaces before entering a storm drain inlet. Some such discharges historically have been widely practiced.

However, in practice, municipal NPDES storm water permit requirements to effectively prohibit nonstorm water discharges have led many MS4 operators to articulate a policy prohibiting all non-storm water discharges to their systems. This outright prohibition avoids the need to make case-by-case determinations of whether discharges are causing water quality problems, and averts potential conflict with USEPA over such determinations. This approach, while possibly efficient from an enforcement viewpoint, suggests overregulation, because nonstorm water discharges that may not have an adverse effect on receiving water quality need to go through costly and unnecessary treatment and disposal. The approach fails to achieve the potential advantages of local environmental control policies.

At the same time, because enforcement requires expenditure of scarce resources and municipal agencies commonly have many responsibilities and competing priorities, many MS4 operators expend little effort ensuring prohibition even when it is specified in their permits. In these cases, non-storm water discharges to MS4s may be in effect under-regulated if some are causing adverse impacts to water quality. The environment may be better protected if a rational policy identifies discharges that are not causing water quality problems in receiving waters and those that are so that MS4 operators may concentrate on enforcement.

For these reasons, the state of California is considering a statewide or global regulatory guidance policy which may be used by municipal permit writers to readily identify types of non-storm water discharges that may be allowed under conditions of a given watershed. This guidance would be consistent with statutory requirements to effectively prohibit nonstorm water discharges and with regulations allowing

R0025379

local determination of acceptable discharges. The underlying principle of the approach is that certain types of nonstorm water discharges may be acceptable in all or most watersheds, and that others dependent on receiving water conditions may be addressed by local determinations. The approach would help achieve consistency in rulemaking among jurisdictions within the state, increase certainty within the regulated community about compliance requirements, and improve efficiency in surveillance and enforcement by MS4 operators and regulatory agencies.

Support for this approach draws from the concept of *de minimis*, or insignificant, impacts of particular discharges. The *de minimis* concept has had varied regulatory applications, including determining acceptable risk from construction and operation of nuclear power plants, describing risk of food additives under the Delaney Clause, and characterizing Superfund liability settlements made by the USEPA. In 1987, Congress in Section 516 of the WQA directed USEPA to study whether some discharges of pollutants are not significant in terms of volume concentration, and type of pollutant, and to identify the most effective and appropriate methods of regulating such discharges (Public Law 100-4, 1987). The resulting report (USEPA, 1991) defines *de minimis* discharges of pollutants as not significant in terms of volume, concentration, and type of pollutant.

The present research, in characterizing knowledge about discharges by type, explores the feasibility of establishing a global approach to effective prohibition of nonstorm water discharges. The approach would be accomplished by developing comprehensive rules for discharges by type: identifying a wide list of potential discharges and considering whether rules by type are effective to control them. Conceptually, an approach based on discharge types would classify discharges according to their pollutant characteristics and potential impacts on receiving water quality. Regulations may specify that classes of discharges be allowed, prohibited, allowed under certain conditions or with certain associated control measures, or subject to case-by-case determination.

Regulations such as USEPA rules for municipal discharges have moved toward rule making based on type of discharge by identifying a number of specific types of non storm water discharges to MS4s that must be addressed in a program to prevent illicit discharges to the MS4 (USEPA, 1990). The rules implicitly accept certain discharge types as potentially harmful in most conditions and other discharge types as *de minimis*, some of these for a given location or set of conditions. This rulemaking is a rational initial step to achieve the regulatory advantages of a global policy within selected jurisdictions, and for a selected small portion of discharge types.

Nonstorm Water Discharges by Industrial Facilities

A large number of regulated facilities reported nonstorm water discharges in annual reports under the General Industrial Permit during 1995. As Table 1 shows, 2,084 discharges were reported by 7,905 facilities in the five evaluated regions, or approximately 0.26 discharges per reporting facility. The proportion was remarkably similar among regions, ranging only from a high of 0.31 discharges per facility in the Central Valley region to a low of 0.22 in the Santa Ana region. This is a large proportion, considering the terms of the General Industrial Permit specify nonstorm water discharges are not permitted. For similar reasons, it is likely the total number of discharges is underreported and the proportion of discharges in each type is more accurate than the total number of discharges.

The most widely reported discharge type in all five regions was landscape irrigation. This accounted for at least 20 percent of reported discharges in each region, with a high of 29 percent in the Santa Ana region. A total of 495 facilities, or about 6.3 percent of all reporting facilities in the five regions, checked the space on the annual report specifying at least one discharge to storm drains of landscape irrigation water.

Some regional differences were demonstrated. Air conditioner condensate accounted for about 15 percent of reported discharges in the Los Angeles region, and 14 percent of discharges in the San Diego region, but only 8 percent of Central Valley discharges. Similarly, discharges from auxiliary water supply for fire prevention and building sprinkler systems accounted for 19 percent of San Diego region discharges and about 10 percent of facilities in all other regions except the Central Valley, where they were only 2 percent of discharges. Conversely, 14 percent of Central Valley discharges were associated with vehicle washing, a larger number than in the other regions, where they were between 5 percent and 7 percent of reported discharges.

Opinion Survey and Municipal Guidance

This section summarizes responses to the broad-based survey and analyzes type based guidelines of selected municipal storm water agencies. The section is divided into three subsections: discharge types where the survey showed consensus for low water quality concern; those with consensus of high or moderately high water quality concern; and discharge types that did not elicit consensus among survey respondents. Each subsection includes guidance for those discharge types from the five municipal

TABLE 1. Nonstorm Water Discharges Reported by Industrial Facilities
Under the General Industrial NPDES Permit, 1995.

Category (Discharge Type)	S.F. Bay		Central Valley		Los Angeles		San Diego		Santa Ana	
	Number	Pct.	Number	Pct.	Number	Pct.	Number	Pct.	Number	Pct.
Cleaning										
Car Washing	0	0	3	1	6	1	0	0	2	1
Floor Washing	0	0	7	1	20	3	3	2	0	0
Pavement Washing	15	4	34	7	29	4	4	2	7	2
Truck and Trailer Washing	11	3	18	4	23	3	1	0	12	4
Vehicle Washing	26	6	69	14	45	7	10	5	16	6
Vehicle Steam Cleaning	0	0	9	2	12	2	4	2	3	1
Window and Building Washing	22	5	20	4	16	2	7	4	11	4
Condensate										
Air Compressor Condensate	19	4	15	3	25	4	2	1	13	4
Air Conditioning Condensate	66	15	40	8	83	12	22	11	41	14
HVAC Condensate	4	1	0	0	0	0	0	0	0	0
Refrigeration Unit Condensate	7	2	4	1	6	1	3	2	4	1
Construction										
Aggregate Pile Cooling Water	0	0	0	0	0	0	0	0	0	0
Construction Rinse Down	0	0	1	0	3	0	1	0	0	0
Dust Control Water	8	2	12	2	8	1	1	0	6	2
Drains										
Tank Drains	0	0	3	1	11	2	0	0	1	0
Filter Drains	0	0	2	0	4	1	2	1	1	0
Fire Fighting										
Fire Auxiliary (building sprinklers)	57	13	10	2	67	10	37	19	28	10
Fire Fighting (emergency only)	0	0	5	1	13	2	2	1	1	0
Fire Hydrant Testing	29	7	49	10	68	10	19	10	33	11
Ground Water										
Foundation Drainage	5	1	4	1	0	0	2	1	0	0
Ground Water Discharge	0	0	7	1	4	1	2	1	4	1
Ground Water Infiltration	12	3	7	1	2	0	4	2	0	0
Treated Ground Water	10	2	0	0	0	0	0	0	0	0
Irrigation										
Landscape/Lawn Irrigation	108	25	104	21	146	21	53	27	84	29
Process										
Boiler Blow-Down	7	2	4	1	31	4	1	0	1	0
Boiler Drains	0	0	1	0	5	1	1	0	1	0
Cooling Tower Back Wash	0	0	6	1	18	3	0	0	7	2
Evaporative Cooling Water	0	0	6	1	6	1	0	0	7	2
Hydrostatic Pressure Vessel Test	0	0	1	0	2	0	1	0	0	0
Liquid-Nitrogen Demineralizer	3	1	0	0	0	0	0	0	0	0
Process Wastewater	0	0	15	3	0	0	4	2	0	0
Noncontact Cooling Water	8	2	7	1	19	3	3	2	0	0
Storage										
Collected Rain Water	9	2	10	2	15	2	4	2	5	2
Water Supply										
Water Line Cleaning	0	0	1	0	3	0	0	0	0	0
Well Water Discharges	0	0	7	1	1	0	1	0	1	0
Well Test Pumping	0	0	3	1	0	0	0	0	0	0
Totals	**426**	**100**	**484**	**100**	**691**	**100**	**194**	**100**	**289**	**100**
Total Number of Facilities Filing NOI as of March 1996	**1455**		**1568**		**2840**		**756**		**1286**	
Discharges Per Facility	**0.29**		**0.31**		**0.24**		**0.26**		**0.22**	

(Note: Percentages may not total to 100 percent due to rounding.)

R0025381

agencies considered, in particular the implications of existing municipal policies for those discharge types.

Survey respondents volunteered a number of discharge types not previously identified in the literature review. No consensus was available for these discharge types, as they were rated only by those respondents who wrote them into the questionnaire. Many of these were minor alterations to types among the 110 identified, but four were notably different and potentially important: washing homeless areas; groundwater discharge mixed with seepage from natural oil discharges; home auto washing; and septage waste hauler spills.

Consensus Low Water Quality Concern. Table 2 summarizes results for 21 discharge types where the survey results suggested consensus of minimal water quality concern. Seven of eight discharge types in the Condensate category met the minimal concern criterion; the only type not listed was condensate from chemical tanks and pipelines. Similarly, four of five types in the Fire Fighting category, and two of three in the Surface Water category, met the criterion for consensus minimal concern.

In the Ground Water and Surface Water categories, the low concern discharge types were naturally occurring: springs, diverted stream flows, and flows from

TABLE 2. Discharge Types With Consensus "Minimal Water Quality Concern" and Current Guidance From Selected Municipalities.

Category (Discharge Type)	Survey Responses: Minimal Concern	Survey Responses: Moderately High Plus High Concern	Survey Responses: Total Responses	Municipal Guidance: Acceptable	Municipal Guidance: Conditional	Municipal Guidance: Prohibited
Condensate						
Air Compressor Condensate	17	1	25			
Air Conditioner Condensate	18	2	25	c,d	b,e	
Air Dryer condensate	19	1	23			
Heat Pump Condensate	20	1	24			
HVAC Condensate	20	1	25			
Refrigeration Unit Condensate	19	1	25			
Steam Condensate	16	1	26			
Drains						
Outside Faucets (routine use)	20	2	29			
Fire Fighting and Safety						
Emergency Eyewashes	20	2	29			
Fire Auxiliary (building sprinklers)	20	1	27	e		b
Fire Hose and Pump Testing	21	1	25			
Fire Hydrant Testing	20	1	29	c,d	b,e	
Safety Showers	24	3	28			
Ground Water						
Springs	18	0	24	b,d,e		
Process						
Ice Maker (melted ice, condensate)	22	1	26			
Surface						
Diverted Stream Flows	19	2	28	b,d,e		
Flows from Riparian Areas, Wetlands	19	1	27	b,d,e		
Water Supply						
Backflow Preventer Testing	16	1	25			
Leaking Potable Water Lines	16	1	25	c		
Pressure Releases	20	0	25	c		
System Failure	16	1	23	c		

Municipal Jurisdictions Considered:

a Alameda County Urban Runoff Clean Water Program (ACURCWP, 1994).

b County of Los Angeles Municipal Permit (RWQCB, 1996; Gary Hildebrand, 1997, Los Angeles County Department of Public Works, Environmental Programs Division, Water Quality Section, Personal Communication to J. Lilien, May 7, 1997).

c Regional Water Quality Control Board, Santa Ana (RWQCB Santa Ana, 1984; RWQCB Santa Ana, 1996).

d County of Sacramento (Larry Walker Associates, 1992; David Brent, 1996, City of Sacramento Department of Utilities, Personal Communication to J. Lilien, November 18, 1996).

e Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP, 1995; SCVURPPP, 1997).

riparian habitats or wetlands. In the Water Supply category, the discharge types identified as low concern are relatively infrequent and/or of small volume. This might also explain why respondents expressed little concern for water quality for discharge types in the Fire Fighting category. Some of these assumptions were tested for a few discharge types using the detailed survey, with results described below.

Table 2 shows reasonably good agreement among municipal agencies' policies regarding categorical controls for these discharge types. Nine of the 21 low concern discharge types were categorically allowed by at least one of the municipalities. (Two of the nine were allowed under specified conditions, each by two municipalities.) One discharge type, fire fighting discharge from building sprinklers, was allowed by one agency but prohibited by another. The other 12 discharge types were not allowed by any of the five municipal agencies.

Consensus High Water Quality Concern. Table 3 summarizes results for 15 discharge types of high water quality concern under the criterion described above. The distribution of opinions was considerably wider than opinions about minimal concern.

All discharge types classified as sewage or spills (of either hazardous or nonhazardous compounds) attained consensus for high concern. This is not a surprising result, and is perhaps not especially meaningful for statewide policy since alternate regulatory controls prohibit such discharges. A similar rationale might explain the consensus for two of the 26 discharge types in the Process category, wastewater and oily waste separators. On the other hand, no clear consensus was identified for the other 24 Process category discharge types. This is surprising given the nature of some of those discharges, such as bilge and ballast water. The result may suggest that site specific conditions may be so variable that statewide

TABLE 3. Discharge Types With Consensus High Water Quality Concern: Survey Results and Current Guidance From Selected Municipalities.

Category (Discharge Type)	Survey Responses: Minimal Concern	Survey Responses: Moderately High Plus High Concern	Survey Responses: Total Responses	Other Regulations
Cleaning				
Equipment Washing	3	20	28	(1)
Washing Process, Storage, Fueling, Loading Areas	6	17	28	(2)
Truck and Trailer Washing	4	18	28	
Landfill				
Leachate	3	17	25	(3)
Process				
Oil/Waste Separator Discharges	2	19	27	(3)
Residential Activities				
Household/Auto Fluids	2	17	23	
Sewage				
Leaking Sanitary Sewer Lines	3	19	28	
Sanitary Wastewater	5	17	27	(3)
Septic Tank Effluent	4	18	26	(3)
Spills				
Hazardous Compounds	3	26	29	
Nonhazardous Compounds	4	11	22	
Transportation				
Gasoline Filling Station Wastes	1	23	28	
Vehicle Dismantling/Parts Storage (fluid drainage)	2	20	27	(2)
Vehicle Maintenance/Repair (fluid drainage)	0	24	28	(2)

(1) Prohibited by two municipal agencies: Alameda County Urban Runoff Clean Water Program (ACURCWP, 1994) and Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP, 1997). No other specific guidance for any of these discharge types from any of the five municipal jurisdictions considered.
(2) Most such discharges are subject to Industrial General NPDES Permit.
(3) Routinely prohibited under other regulations.

R0025383

policies are not supported for these discharges. Alternately, perhaps responding experts were not sufficiently familiar with these discharge types to produce consistent results. This result implies that some California storm water experts may be willing to accept certain process discharges if the specific process activities and chemical composition of the discharge are well known and carefully controlled.

Of the five discharge types in the Transportation category, three achieved consensus for high concern. All three were associated with vehicle maintenance and fueling activities. In the Cleaning category, only three of the 14 discharge types showed consensus, and all were similar to Transportation category activities: one was fuel related; one was washing of trucks and trailers; and the third was equipment washing. This result suggests that nonstorm water discharges associated with transportation activities in general may be widely considered for prohibition at the statewide policy level.

Almost none of the 15 discharge types meeting the criterion for consensus high concern were addressed by municipal storm water guidelines. The only exception was process equipment washing, explicitly prohibited by two municipalities. This does not suggest the five municipalities had no concerns with the other discharge types, but rather they had not identified a need to promulgate controls under storm water regulations. As shown on Table 3, most discharge types of this group were addressed at least peripherally under regulations or controls specified for hazardous wastes, wastewater discharges, or other activities. It is not surprising to find strong consensus on high water quality concern with discharge types long recognized as problems and controlled under a variety of regulations. The converse result, that the surveyed group did not identify other discharge types with high water quality concern in their own jurisdictions, implies no other types by nature were necessarily so great a water quality threat that categorical prohibition was urgently needed, at least in the opinions of these individuals.

Discharge Types With Absence of Clear Consensus. Table 4 lists discharge types where no consensus was achieved among survey respondents. It is not surprising this was the largest group, both because of the restrictive criteria for consensus and the diversity of interests of the survey respondents. Results showed substantial diversity of opinion.

Many discharge types received multiple scores of 4 and 5, while also receiving multiple responses with a score of 1. Four Cleaning category discharge types received more than 10 responses of 4 or 5, and none of the 11 nonconsensus types received fewer than five such scores. Each also received numerous scores of 1: three to five respondents expressed minimal concern with vehicle and pavement washing, and at least 10 respondents expressed minimal concern with washing buildings, windows, and graffiti marked surfaces. A similar diversity, though somewhat less extreme, was evident among the 23 nonconsensus discharge types in the Process category, and all three types in the Mining category, which may be considered process oriented.

This high diversity of opinion may be attributable to a number of factors, as discussed above. The results suggest that current knowledge of these discharge types is not sufficient to support statewide policies, and that additional research is needed on the diversity of characteristics of these discharge types. The nonconsensus discharge types might be considered of high priority for future field research to quantitatively characterize potential pollutants and determine if characteristics are sufficiently uniform to support statewide policies.

The diversity of opinions was further evident in the municipal guidelines. Of the 80 discharge types on Table 4, 22 were categorically prohibited by at least one of the five agencies; 21 were allowed unconditionally by one or more municipalities; and conditional exceptions were found in at least one municipality for 23 discharge types.

A total of 29 different discharge types were either categorically or conditionally allowed by at least one of the five municipalities. Only 12 of these 29 types were allowed by three or more of the five municipalities, a strong piece of evidence for the lack of uniformity in different California agencies' approaches. The most surprising result is that five of the discharge types for which at least one municipality promulgated a categorical prohibition were either categorically or conditionally allowed by at least one other municipality. Further, a large number of discharge types allowed by one or more municipal agencies, presumably because they generated minimal concern for water quality impacts, did not achieve consensus of the surveyed experts for the same minimal concern.

The inconsistency of municipal guidelines demonstrates varying responses by local decision makers to incomplete information about water quality impacts. Many discharge types were allowed in some municipalities without restriction, and prohibited in other municipalities. It is not clear how much of the diversity may be attributed to regional differences, such as varying sensitivity of receiving waters or varying political climate as expressed in a preference to avoid burdensome environmental controls on local businesses. It is not considered likely the pollutant content of the discharges themselves should be strongly different among regions, though variability is expected among individual discharges. The frequency of certain

TABLE 4. Discharge Types With Municipal Guidance for Which Survey Results Did Not Achieve Consensus: Survey Results and Current Guidance From Selected Municipalities.

Category (Discharge Type)	Survey Responses: Minimal Concern	Survey Responses: Moderately High Plus High Concern	Survey Responses: Total Responses	Municipal Guidance: Acceptable	Municipal Guidance: Conditional	Municipal Guidance: Prohibited
Cleaning						
Car Washing (residential)*	3	9	29	d	b,e	a
Car Washing (commercial)*						a,b,e
Carpet Cleaning**						e
Cooling Tower Heat Exchange Flushing	7	7	26			
Exterior Building Washing	10	7	29			e
Floor Washing	9	11	28			e
Graffiti Abatement	12	5	26			e
Laundry Wastewater	8	9	27			
Mobile Cleaning Activities**						a,e
Pavement Washing	4	14	29	e	a,b	
Process Areas Washdown**						a
Restaurant Wash Water**						a,e
Storm Drain System Residual Flushing	10	13	29			
Street Wash Waters	7	9	28	e	b	
Vehicle Cleaning	5	14	28			a,e
Window and Building Washing	15	6	29			
Condensate						
Chemical Tank/Lines Condensate	9	4	26			
Construction						
Construction Dewatering	2	11	26	c		e
Construction Equipment Washing**					c	a,e
Construction Rinse-Down	1	13	25		c	e
Dust Control Water	11	2	27		c	
Geotechnical Construction**					c	
Material Storage**					c	
Sand Dredging	7	3	19		c	
Saw Cut Slurry**						e
Drains						
Filter Drains	6	6	27			
Fountain/Reflecting Pool Drains	10	6	27			e
Swimming Pool Discharges	2	6	25	a,c	b,d	e
Fire Fighting						
Fire Fighting	10	7	27	b,d	e	
Groundwater						
Aquifer Restoration	7	2	18			
Brine Discharges (stripper wells)	2	11	23			
Dewatering of Vaults and Crawl Spaces	7	4	19	d	b,c,e	
Foundation Drains**				e	b,e	
Footing Drains	10	2	24	d	b,e	
Ground Water Infiltration	12	1	25	d,e	b	
Pumped Ground Water	10	0	24	d	e	
Rising Ground Water	15	1	27	d,e	b	
Treated Ground Water	15	1	27			
Water Well Discharges	15	0	27			
Well Development	9	3	27	c		
Well Test Pumping	13	2	27	c		
Irrigation						
Irrigation Water	9	5	28	b,d	e	
Landscape Irrigation	9	7	28	b	e	
Lawn Watering	7	6	28	b,d	e	
Seeps and Similar Discharges	6	12	22			

TABLE 4. Discharge Types With Municipal Guidance for Which Survey Results Did Not Achieve Consensus: Survey Results and Current Guidance From Selected Municipalities (cont'd.).

Category (Discharge Type)	Survey Responses: Minimal Concern	Survey Responses: Moderately High Plus High Concern	Survey Responses: Total Responses	Municipal Guidance: Acceptable	Municipal Guidance: Conditional	Municipal Guidance: Prohibited
Process						
Aggregate Pile Cooling Water	5	5	18			
Bilge and Ballast Water	4	10	21			
Boiler Blow Down	3	9	23			b
Boiler Drains	4	8	24			
Chiller Water	6	6	22			e
Cooling Tower Water	4	7	24			b,e
Dust Control	9	1	24			
Evaporative Cooling Water	10	3	22			
Fish Hatcheries	8	5	20			
Hot Water Temp./Press. Relief Valve	13	1	24			
Humidifier Blow Down	15	2	23			
Leaking Tanks and Pipes	2	12	24			
Locomotive Sanding	5	7	15			
Noncontact Cooling Water	14	5	25	c		
Pressure Relief Valves	11	2	23			
Quarries	3	6	19			
Sand Blasting	1	13	24			
Saw Slurry	1	8	25			
Scrap Turnings	1	6	18			
Seafood Packaging and Processing	3	11	18			
Separators – Liquid/Steam Water	4	5	23			
Textile Mile Reused/Recycled Water	4	7	17			
Vacuum Pumps	5	3	19			
Residential Activities						
Motor Home Waste**						e
Fertilizers/Pesticides**						e
Sewage						
Sanitary Sewer Overflow**						e
Storage						
Collected Rain Water	13	2	26	b		
Hydrostatic Testing	9	3	24	b,c		
Water Softener Tanks	7	10	25			
Surface Water						
Pit Dewatering	8	5	26			
Transportation						
Aircraft Deicing	3	12	23			
Inductive Traffic Loop Flushing	3	6	15			
Water Supply						
Reservoir Flushing	13	3	25	c		
System Maintenance	12	2	23	c		
Water Filtration Plants**						
Water Line Flushing/Cleaning	12	4	27	b,c,d	e	

*Commercial vs. residential car washing was not distinguished in survey.
**Not included in survey in the same form as covered by municipalities' guidelines.

R0025386

Municipal Jurisdictions Considered:

a Alameda County Urban Runoff Clean Water Program (ACURCWP, 1994).
b County of Los Angeles Municipal Permit (RWQCB, 1996; Gary Hildebrand, 1997, Los Angeles County Department of Public Works, Environmental Programs Division, Water Quality Section, Personal Communication to J. Lilien, May 7, 1997).
c Regional Water Quality Control Board, Santa Ana (RWQCB Santa Ana, 1984; RWQCB Santa Ana, 1996).
d County of Sacramento (Larry Walker Associates, 1992; David Brent, 1996, City of Sacramento Department of Utilities, Personal Communication to J. Lilien, November 18, 1996).
e Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP, 1995; SCVURPPP, 1997).

discharge types may vary among regions, as shown above in the evaluation of discharges from industrial facilities, but no evidence suggests municipal agency guidelines vary among regions in a similar pattern to varying frequency of industrial discharges.

The large number of discharge types allowed under specified conditions suggests reasonably wide support for that mechanism. Conditional permitting could achieve the benefits of exempting from prohibition discharges believed to have minimal water quality impact. However, conditional permitting is considerably more costly than type based prohibition or permitting, both to develop permits and to enforce. Further, lack of adequate enforcement may lead to routine violation of conditions and possible water quality impact.

Results of Detailed Questionnaire for Selected Discharge Types

Results of the detailed survey are described in Duke *et al.* (1997) and not repeated in detail here. Table 5 summarizes one aspect of the results, the number of responses of 4 or 5 to each of nine questions for each of the ten discharge types.

Two discharge types were given scores of 4 or 5 by a majority of respondents for the question of "overall concern," intended to be the same question as the broad based survey. Construction equipment washing, a subset of the equipment washing discharge type that achieved consensus high concern in the broad based survey, was so ranked by nine respondents in the detailed survey. Further questions revealed 11 of the 12 respondents would have high concern if the discharge were widespread or "prevalent" in their region. The reasons for the concern were pollutant concentration and types rather than discharge volume for most of the respondents. Fire fighting discharge, which did not elicit consensus on the broader survey, showed the second largest number of respondents with high concern, again attributable to pollutant concentration and types rather than volume.

Nine of the ten selected discharge types, with the notable exception of landscape irrigation, were found by the respondents to be of much less concern if they were subject to on-site controls or Best Management Practices (BMPs). Each respondent was asked to describe the best currently available BMPs with which he or she was familiar for each discharge type; then to describe their degree of concern if those BMPs were fully implemented for each discharge of that type. No more than one respondent expressed moderately high or high concern for any of the nine discharge types if the selected BMPs were rigorously implemented. The availability of BMPs for these

TABLE 5. Results of Detailed Survey for Selected Discharge Types: Number of Respondents Expressing "Moderately High" Plus "High" Concern.

Category (Discharge Type)	Current Concern (overall)	Concern If Discharges Were "Prevalent"				Concern if BMPs Were Implemented			
		Overall	Discharge Volume	Pollutant Concentration	Pollutant Types	Overall	Discharge Volume	Pollutant Concentration	Pollutant Types
Condensate									
Industrial Cooling Eqpt. Condensate	0	0	1	1	0	0	0	0	0
Chemical Tanks/Lines Condensate	2	2	1	2	2	0	0	0	0
HVAC Eqpt. Condensate	0	0	1	0	0	0	0	0	0
Construction									
Dust Control Water	0	3	2	3	1	0	0	0	0
Equipment Washing	9	11	1	10	10	1	0	1	1
Fire Fighting and Safety									
Fire Fighting Discharge	6	7	4	8	8	0	0	1	1
Fire Hose, Hydrant, Pump Testing	1	3	3	2	2	0	0	0	0
Groundwater									
Dewatering Industrial/Urban Vaults	1	3	1	5	6	0	0	1	1
Irrigation									
Landscape Irrigation – Urban, nonagricultural	3	7	2	6	9	1	1	3	4
Storage									
Rainwater Collected in Secondary containments	3	4	1	4	5	0	0	1	1

Total of 12 responses to survey, July 1995.

R0025387

discharge types supports the concept of conditional allowability, the mechanism noted above in discussion of municipal guidelines for many of the non-consensus discharge types in Table 4.

The landscape irrigation discharge type elicited high overall concern from only three of the 12 respondents under current conditions, but seven respondents expressed high concern if the discharge type were prevalent. This result is notable because the review of industrial facility reports showed this as the single most common discharge type, being reported by about 7 percent of all industrial facilities filing annual reports for five regions of California in 1995. Further, it is a discharge type that appears resistant to on-site pollution prevention, compared to others, because this is the only discharge type where more than one respondent described high concern even if best available controls were rigorously implemented.

CONCLUSIONS

This research acquired data to assess the conceptual and technical feasibility of an approach for nonstorm water discharges to relieve the regulatory burden of developing and issuing individual permits that would use discharge type as the basis for regulation.

The first objective was to determine the policy basis for such an approach. Currently, compliance with relevant regulations is often inefficient as practiced. Outright prohibition of non-storm water discharges overregulates by prohibiting some discharges that may not affect water quality. "Effective prohibition," specified by WQA, is interpreted by USEPA to allow individual discharges under separate NPDES permits, but such permits are not widely utilized by municipalities operating MS4s because they are administratively complex, burdensome to develop and enforce, require detailed evaluation of individual discharges, and are subject to USEPA overrule of local judgments.

A possible improved approach merges two concepts derived from current instruments: determination of *de minimis* discharges; and consideration of nonstorm water discharges by functional type. The resulting approach would define *de minimis* discharge types which may be globally accepted for discharge to storm drains. Allowing certain such discharges under blanket statewide guidelines can relieve the regulatory burden and avoid the expense of controlling activities with little expected environmental impact. Any policy eventually promulgated should be based on both technical analysis, which may be guided by this paper's preliminary effort, and a full assessment of stakeholders' preferences about costs, regulatory effectiveness, environmental protection, and other factors.

The second objective was to characterize existing information by discharge type. The evaluation produced three major results:

- A large number of discrete types of nonstorm water discharges exist. More than 100 distinct types of discharges were found in the literature, and several more were suggested by survey respondents.
- Nonstorm water discharges appear to be widespread. Approximately one in four industrial facilities in five California regions reported at least one type of discharge during the 1995 reporting year, even though such discharges were required to be eliminated under permit conditions.
- Some discharge types were widespread in industrial facility reports. For example, runoff from landscape irrigation was reported by nearly 500 facilities within five regions of California, more than 6 percent of all reporting facilities.

The third objective was to characterize the current state of knowledge about concerns with potential water quality impacts of nonstorm water discharges by discharge type. An integral part of this objective was to test the strength of consensus among practitioners and responsible agencies – to determine whether current knowledge supports statewide policies for any discharge types. Two forms of information, evaluation of existing municipal guidelines and a consensus oriented survey of statewide experts, addressed this objective, and suggested the following results:

- Clear consensus existed about water quality concern for some discharge types. The limited survey, with a convenience sample of experts, implemented by this research was sufficient to demonstrate some consensus.
- Discharge types that achieved consensus for minimal water quality concern were not uniformly allowable under current municipal guidelines in California.
- Discharge types that achieved consensus for high water quality concern were almost entirely limited to discharge types readily recognized as important sources of water quality degradation. Most of these were prohibited under existing regulations not related to storm water; few were explicitly prohibited by municipal guidelines designed for storm water pollution control.
- Municipal agency control policies in different regions of California were highly inconsistent for specific discharge types, especially among discharge

types that did not achieve consensus in the statewide survey. This suggests the current state of knowledge is not sufficiently definite to support statewide policies for a large number of discharge types.

• Discharge types failing to achieve consensus might be considered the highest priority for additional research. These are the types where feasibility of global policies could be justified or counterindicated by better understanding of potential water quality impacts, such as field data to characterize pollutants originating with these activities and understanding of conditions under which pollutants are found in higher concentrations.

The discharge types were evaluated largely as found in the literature in order to be as completely inclusive as possible in this initial stage of analysis. Critical analysis of discharge types should be a focus of future research. Aggregating and analyzing discharge types according to similarities in pollutants, function, applicable best management practices, and other factors may facilitate implementation of policies based on discharge type.

An in-depth survey requesting opinions on a limited number of discharge types revealed three notable results with policy implications:

• Discharge types for which respondents expressed high concern for water quality impacts generated most of the concern from two factors, type and concentration of pollutants, and relatively little to volume of discharge.

• For nine of the ten selected discharge types, almost none of the respondents expressed high concern if currently available BMPs with which they were familiar were rigorously implemented. The survey did not, however, address whether the respondents believed such BMPs could be effectively enforced or would be rigorously implemented if regulations so specified.

• Landscape irrigation was one discharge type for which opinion suggests high impact if prevalent. This discharge type was the most widely prevalent among industrial facilities. It was also the only discharge type of the ten selected for in-depth opinion polling where a substantial number of respondents believed currently available BMPs would not reduce concerns to minimal if rigorously implemented.

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R0025389

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Pollutants in storm water runoff from metal plating facilities, Los Angeles, California

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Abstract

This research evaluated storm water runoff water quality constituent data collected by industrial facilities under California's 1992 General Industrial Storm Water NPDES Permit. Data for 13 constituents were evaluated for a sample of 130 metal plating facilities in Los Angeles County, reported over a 3-year period. Results are intended as a screening level determination of several factors: proportion of facilities detecting the constituents; their concentrations in a single-industry, single-region set of facilities; and possible trends over time. The analysis also tested the limitations of the self-reported data, which report concentration rather than load and may not be representative of facility runoff. Zinc and copper were detected at more than 80% of facility locations; nickel, chromium, lead, and cadmium were detected at more than 25% of locations. Mean concentrations of copper, lead, zinc, suspended solids, and oil and grease at sample facilities testing for the constituents were roughly comparable to mean concentrations reported by US EPA for a similar set of data from a nationwide sample of metal products manufacturing facilities. As a fraction of water quality standards, median concentration at facilities detecting the constituents were relatively high for copper and silver compared to standards for aquatic life, and for cadmium and lead compared to human drinking water standards. Trends over the 3-year period in concentration of pollutants in facility runoff that may result from regulatory pollution prevention requirements were inconclusive. The concentration data show evidence of other confounding influences sufficiently large and systematic to obscure possible trends in pollutant reduction.

1. Introduction

Pollutants in storm water runoff associated with industrial activities are one form of industrial waste discharge of increasing concern in the US. Urban runoff and other non-point sources are believed to be important sources of pollutants in surface waters of the United States [1–3]. Runoff from urban activities has been estimated to account for substantial proportions of the total mass of some pollutants in some receiving waters [4].

The proportion of pollutants in urban runoff originating with industrial activities relative to other non-point sources has been suggested to be substantial in some areas of the US [4,5]. Research under the Nationwide Urban Runoff Program (NURP) in the 1970s and 1980s suggested concentrations of certain pollutants are significantly higher in runoff from industrial areas than from other land uses [6,7]. However, the characteristics of chemical constituents in runoff from industrial facilities, and their impact on receiving waters, are not well understood. Pollutant type, concentration, and long-term load may be expected to vary over time and across locations with factors such as density of urban development, types of industrial activities, seasonality of precipitation, and proportion of receiving waters originating as urban runoff. These variables and others, such as ecological sensitivity of receiving waters, confound assessment of environmental impacts of urban runoff [8]. The same factors obscure the potential impacts of industrial storm water regulations on improving water quality.

Differences in runoff constituent characteristics among different types of industrial activities are poorly understood. The groundbreaking NURP studies sampled only a small number of industrialized areas, limited to industrial parks and urban areas with a large proportion of land zoned for industrial uses, and did not

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R0025391

distinguish among different industrial sectors or types of activities [6]. It is not clear that runoff constituent concentrations from industrial activities are sufficiently uniform to be adequately represented by measured discharges from areas zoned for industrial use, which can encompass industrial activities as diverse as metal products manufacturing, lumber and wood processing, concrete products storage and preparation, warehousing, and a wide range of other manufacturing and non-manufacturing activities.

Systematic data for a large number of facilities, disaggregated by type of industry, first became available with US EPA's analyses of self-reported monitoring results for 31 distinct industrial sectors from a nationwide sample [9]. The nationwide US EPA sample encompassed many facilities subject to a wide range of climates, rainfall regimes, state and local level regulations, and other factors. Those results therefore may not reliably predict pollutant concentrations within industry sectors for any given geographic area. The self-reported nature of the data introduces other limitations, as described in the Methodology section below.

Other results in the literature are limited. Line et al. [10] reported runoff concentration data for selected constituents at 20 North Carolina industrial sites encompassing 10 different sectors. Line and colleagues' results are much better controlled for data acquisition and geographic area of facilities than the US EPA data. However, the samples of two facilities per industry category is too small to capture the variability in pollutant-generating activities present within a given industrial sector. Both studies were limited because they evaluated runoff concentration data, an imperfect surrogate for pollutant loads, the factor arguably most useful for identifying impacts on the environment and assessing effectiveness of pollution prevention. To the authors' knowledge, no agency analyses or published research completed to date has systematically evaluated a sample of industrial facilities to characterize annual load of pollutants by sector.

In the US, regulations to reduce pollutants conveyed in runoff from industrial facilities have been promulgated by US EPA under the National Pollutant Discharge Elimination System (NPDES) of the 1972 Federal Water Pollution Control Act (Clean Water Act, or CWA) and the subsequent 1987 Water Quality Act (WQA) [11]. The most recent federal regulation includes specific requirements for each of 29 different sectors, and is known as the NPDES Storm Water Multi-Sector General Permit for Industrial Activities (hereinafter, the Multi-Sector Permit) [12]. States with authority to enforce the CWA have developed state-level regulations largely patterned after US EPA guidelines. California, the jurisdiction of interest for this paper, promulgated a General NPDES Permit for Storm Water Discharges Associated with Industrial Activities (hereinafter, the General Industrial Permit) [13], first effective in 1992 and renewed in 1997. The number of facilities subject to the regulation is known to be large, perhaps in the range of 30,000 to 50,000 in California, but is not well-defined, for reasons described elsewhere [14]. As of January 1997, about 10,000 industrial facilities in California (of which about 2500 were in Los Angeles County) had notified state agencies of their intent to comply with the General Industrial Permit.

Federal and state storm water permits take a pollution prevention approach. Facility operators are required to develop a site-specific Storm Water Pollution Prevention Plan (SWPPP) with Best Management Practices (BMPs) designed specifically for their facility. This approach contrasts with the discharge standards of the NPDES wastewater discharge permit system, which specify numerical discharge limitations based on available control technologies. A significant limitation of the storm water regulatory structure is the inherent difficulty in evaluating both compliance by the regulated community and progress in reducing pollutants in discharges. The structure of the regulations and reasons for those limitations are described in more detail in a previous publication [15].

A key feature of the regulations is that facilities annually monitor storm water discharges by collecting runoff samples, conducting laboratory analyses to quantify certain constituents in the runoff, and reporting the results to the responsible agency [11]. As a result, a body of data on runoff constituents has accumulated since 1993 in the hands of state agencies. The intent of the monitoring requirements is clearly both to provide information to facility operators so they can detect potential problems and evaluate their own BMPs' effectiveness, and to allow regulators to assess progress both on a facility-specific level and at the level of aggregate pollutant discharges into particular watersheds [16]. If the data were reliable, they might also serve the purpose of characterizing discharges by industry sectors and by industry as a whole in a form that would support regional, state, and local decisions about controlling pollutants to most effectively protect receiving waters.

The data are not ideal for those purposes, for a number of reasons. Data generated under the monitoring requirements are limited to grab samples of runoff collected once or twice per year, and analyzed for concentration of a small number of constituents specified in the regulations or judged by the facility operator as likely to be present. A more thorough understanding of a facility's runoff characteristics would require evaluating pollutant loads generated over an entire wet weather season, or alternatively evaluating long-term average concentrations using data from flow-weighted composite samples collected during representative storms throughout a season. Other reasons are explored in more detail in the Methodology section below.

The existence of the broad and time-specific collection of data accumulated under the General Industrial Permit allows some evaluation of certain major areas of uncertainty such as those described above. Despite the acknowledged limitations, no better data are available at present for such assessments. It is clearly important those assessments be conducted to the extent currently possible to support ongoing efforts to protect specific receiving waters and to evaluate effectiveness of regulations that impact tens of thousands of businesses in California. The overall purpose of this paper was to illuminate key areas of uncertainty regarding runoff constituent characteristics from a given industrial sector in a given geographic area, in the context of assessing progress by facilities in reducing constituents in their runoff under the regulations' pollution prevention approach. The analysis is proposed as a necessary first step in understanding the current and potential impact of regulatory controls. The analysis presented in this paper is intended to derive all conclusions the available data are capable of supporting, although those conclusions ultimately are quite limited. A second important purpose of this paper was to assess the usefulness of the monitoring data being collected. The limited conclusions we have achieved demonstrates the incomplete nature of the data, and suggests potential improvements in the data that would support other conclusions essential to assessing effectiveness of the regulations.

The general objective of this research was to evaluate water quality discharge constituent data for a sample of industrial facilities to assess sector-specific pollutant discharge characteristics, and their changes over the time since the General Industrial Permit has been in effect. There were four specific objectives. First, the research evaluated constituent concentration data for a single industry sector in a single geographical region, comparing results to those of other sector-specific analyses. This is a screening-level evaluation upon which future research can build, preferably with load-based discharge data. Second, the data were analyzed for information that might be immediately useful in regulatory decisions, specifically regarding which constituents should be required for analysis by facilities of the metal finishing sector. Third, the research attempted to identify any impact of pollution prevention efforts implemented under the storm water regulations for the selected industry sector that may be observed from the self-reported monitoring data. The research accomplished this by investigating changes in water quality constituent concentration from a sample of facilities that had recognized their duty to comply. This result also was a screening-level determination, intended to draw conclusions about the ability of the monitoring data to capture any such trends as well as about the trends themselves. Fourth, the research analyzed limitations to this approach, assessed the usefulness of self-reported monitoring data for these purposes, and recommended modifications to regulatory requirements that might generate data better suited to such evaluations.

2. Methodology

The research evaluated self-reported data of chemical constituent concentrations in storm water runoff from industrial facilities of the metal plating industry in the greater Los Angeles, CA, geographic area. Data were reported to the California Regional Water Quality Control Board, Los Angeles (RWQCB/LA), under the General Industrial Permit. Data were analyzed in three ways. First, data from the sample were compared to similar data from US EPA [9] and Line et al. [10] to improve understanding of discharge characteristics from the selected industry sector and to assess the current degree of understanding by testing similarity of different studies' results. Second, data were evaluated for specific results of interest to the regulatory sector. In particular, two factors were of immediate interest: the proportion of facilities identifying presence of certain constituents; and the median concentrations of these constituents in facilities where they were identified compared to their potential effects in the environment. Third, data were evaluated to attempt to detect trends in discharge characteristics within the sample over the 3-year period for which monitoring results are available to date.

A single industrial sector was evaluated to reduce variability in results from the influence of factors such as widely different production technologies and schedules. The metal finishing industry was selected for a number of reasons. It is subject to the General Industrial Permit; it is represented by a large number of facilities filing monitoring reports under the General Industrial Permit; and it is of concern to storm water quality because a typical facility makes use of many toxic substances that may be present in storm water discharges. A single region was used to avoid the influence of potential confounding factors such as difference in regulatory climate, economic strength and environmental awareness. Los Angeles County was chosen because it has the largest number of industrial facilities reporting under the General Industrial Permit of all counties in California [17].

2.1. *Data acquired for Los Angeles metal plating facilities*

The present research acquired data from metal finishing facilities that had filed a Notice of Intent (NOI) to comply with the General Industrial Permit, and had subsequently submitted annual reports containing monitoring data for at least one year of the period 1993 through 1995. That definition does not cover all metal finishing facilities in the Los Angeles region both because of incomplete compliance and because the regulations do not apply to all facilities. The metal finishing industry is part of Sector AA of US EPA's Multi-Sector Permit, defined as fabricated metal products manufacturers. Under the Multi-Sector Permit and the General Industrial Permit, facilities in Sector AA need to comply only if their industrial activities are exposed to storm water.

As of 1995, 180 facilities in Los Angeles County had filed NOIs identifying on-site industrial activities to include operations described by Standard Industrial Classifications (SICs) 3471 through 3479, electroplating and metal finishing. By comparison, the US Bureau of the Census identified 391 facilities in Los Angeles County with SICs 3471 through 3479 for calendar year 1993 [18]. Not all 180 NOI filing facilities submitted monitoring results for all years, and some failed to meet this requirement in any of the three years. Data for one or more years were acquired from a total of 130 facilities.

The 130 facilities tested for a variety of constituents. The 1992 version of the General Industrial Permit specified only four constituents for which all facilities were required to analyze their samples: pH, total suspended solids (TSS), specific conductance, and total organic carbon (TOC). The parameter oil and grease (O & G) was permitted to be substituted for TOC. The General Industrial Permit also specified runoff be tested for other pollutants the facility operator judged likely to be present. For the metal finishing industry, this might reasonably include a number of metals and other substances used in plating chemistries, such as cyanide. More recent regulations, promulgated by US EPA under the Multi-Sector Permit, specify four additional mandatory analytes for Sector AA: total iron; total aluminum; total zinc; and nitrate plus nitrite nitrogen. Those requirements were not in place at the time the data evaluated here were collected. Constituents for which at least one facility in the sample conducted analyses in any of the three target years are listed in Table 1 divided into mandatory constituents, metals, and others.

Data for this research were collected for a total of 13 constituents: three "conventional" pollutants, nine metals including arsenic, and cyanide. These are also identified in Table 1. The number of sample facilities testing for each constituent varied from year to year and among constituents. Aluminum and iron were not selected for this research because few facilities of the sample reported test results for either aluminum or iron. The more recent Multi-Sector Permit requirements specify aluminum and iron for mandatory testing, but few facilities of this sample elected to test for them because they are much less important to a typical metal finishing operation than plating metals (such as chromium and copper), and they are much less likely to be present in plating facilities' runoff than at other facilities of the fabricated metal products industry. Similarly, no nutrients were selected, because fewer than 10 facilities of the sample tested for any nutrients, although three nutrients were included in the US EPA data: phosphorous, total Kjeldahl nitrogen, and nitrate plus nitrite nitrogen. Specific conductance was not selected because it is known to correlate poorly to suspended and dissolved solids and is not a meaningful parameter for other pollutants. Finally, this research did not evaluate pH data. Acidity of facility runoff may be expected not to vary far from neutrality, except in cases of an immediate spill of caustic or acidic substances.

Table 1
Substances in monitoring reports by one or more facilities in the Los Angeles metal platers sample, 1993 to 1995

Mandatory testing	Metals	Other
pH	Aluminum	Cyanide[a]
TSS[a]	Antimony	BOD
Specific conductance	Arsenic[a]	COD
Oil & grease[a]	Barium	TTO
TOC[a]	Beryllium	Benzene
	Cadmium[a]	Toluene
	Chromium[a]	Ethylbenzene
	Cobalt	Total xylenes
	Copper	Acetone
	Iron	Surfactants
	Lead[a]	Hardness
	Mercury[a]	Turbidity
	Molybdenum	BAS
	Nickel[a]	TDS
	Selenium	
	Silver[a]	
	Thallium	
	Vanadium	
	Zinc	

[a] Constituent selected for this research.

Concentration data for each constituent for each facility were conditioned as follows. For facilities where the monitoring plan included sampling at multiple on-site locations, each location was treated separately. Multiple-location sampling was intended by the General Industrial Permit only where facilities are composed of physically and hydraulically separated areas, so concentrations from different sampling points are not expected to be correlated, justifying treatment as independent data points. Data for multiple samples from a given location, on the other hand, were expected to be correlated, especially those representing multiple grab samples from a single storm event. To control for this correlation, we produced a single data point for each location by arithmetically averaging all concentration data reported in a single year for a single location.

Non-detect data were treated in two different ways for different analyses. If a given constituent was detected in only one runoff event of a given year, the concentration value for each non-detect event was assigned to be one-half of the detection limit reported by the facility (varying among facilities). This approach conservatively assumed the constituent was likely to be present in some amount at a given facility during any runoff event of a year in which it was shown to be present at least once.

On the other hand, if all sampling events failed to detect a given constituent in a given year, we replaced the non-detect value with zero. While this approach is not consistent with the more conservative analysis described above, it was adopted to allow comparison with summary statistics published elsewhere [9], one of our goals in this paper. The rationale for this method is to avoid presuming the constituent to be present in any amount at all facilities, on the grounds that facilities where a substance is not in use may actually discharge zero mass of the constituent in runoff. Facilities with at least one event detecting a constituent are less likely to discharge zero mass in the next event.

However, using that method, the computed sample mean and variance for concentration data are strongly affected by non-detect occurrences replaced by zero values. Those statistics are, thus, strongly affected by the selection of facilities in the sample and, in turn, by choices of sample facility operators whether to conduct analyses for certain constituents. That is because data submitted by facilities where constituents were absent strongly affects the computed mean and variance, while facilities where operators chose not to test for the same constituent do not affect mean and variance. We calculate mean concentrations and standard deviation for comparison to US EPA results [9] but because these statistics are affected by sample selection, we suggest they are not meaningful in our further goal of characterizing expected runoff concentration at a facility where the analyte constituent is in use. Instead, analysis in the following section uses the median for a central tendency statistic, and calculates the median using detected values only. We suggest that parameter is more useful to estimate constituent concentrations typical of an industry sector.

The available data are inherently limited by the structure of the regulations, for several reasons. The self-reported chemical constituent data may not be representative of varying concentration in facility runoff with changing industrial activities and changing long-term conditions. Little agency guidance was provided [19], and little enforcement effort was made to verify adequacy.

One reason is spatial variability of industrial activities. The General Industrial Permit specifies samples should be collected from locations "representative" of the facility's runoff pollutants, but regulatory oversight was not adequate to ensure facilities collected runoff from areas including industrial activities.

Another key reason is variation in constituent concentration with time. Within a given storm, constituent concentration during early stages of runoff is likely to be different than after hours of rainfall have washed exposed industrial surfaces. Regulations do not stipulate at what point in a storm runoff should be sampled, so data from multiple facilities were not collected in a consistent manner. Also, sampling requirements were satisfied by grab samples, which are unlikely to capture the average concentration within a given storm event. Few facilities in the sample collected runoff composites, and these were excluded from the analysis because data would not be comparable to the grab samples of the other facilities.

Further, concentration may be expected to vary among different storm events. Facilities were required to collect storm water samples during the wet weather season from only a small number of runoff events—one storm in the 1993 season, and two storms for all seasons thereafter. (The more recent Multi-Sector Permit stipulates a total of two samples, one each during the second and fourth year of the permit, for the four additional constituents added by the new regulations.) It is unlikely that sampling data from one or two storms each year is representative of constituents generated by changing manufacturing activities and other conditions at a typical, operating manufacturing facility.

Finally, some data were missing. Facilities were required to sample storms only if significant runoff commenced during normal operating hours or within the 2 h following scheduled facility operating hours. Some metal platers in the Los Angeles sample claimed not to have experienced two storms sufficient for runoff sampling in a given wet weather season, and therefore failed to submit any analyses for some years—the reason data were available for only 130 facilities of the 180 filing NOIs.

Data were also of questionable consistency among facilities. Each facility was required to develop and implement its own monitoring plan, adapted to measure any pollutants that might originate with the facility's particular industrial activities. Since regulatory agencies did not prescribe or enforce a standard methodology, the sampling and monitoring procedures may vary sharply among facilities. Of greater concern are the potential variability and inadequacy in quality assurance and quality control protocols, which also receive little regulatory oversight. Facility personnel may be expected to vary widely in training, expertise, and diligence in storm water sampling.

Limitations in available data suggest this research ideally should be replicated with well-controlled data collected especially for loads analysis under consistent research methods, for example using flow-weighted composite samples over multiple years. However, collection of data over multiple years from a sufficiently large sample to be statistically meaningful would be prohibitively costly and time consuming. A careful analysis of currently available data is justified before more extensive efforts are conducted.

2.2. Data characterization and comparisons to other published data

Our results compare data acquired for the Los Angeles sample of metal platers to data reported by US EPA for group-applicant facilities of Sector 29, Fabricated Metal Products [9]. Sector 29 is analogous to Sector AA in the Multi-Sector Permit; both are broader sets of related industrial activities that encompass metal finishing activities. It is the most closely related sector for which US EPA data are available. The sample size was roughly comparable, composed of 115 reporting facilities, not all of which tested for every constituent.

The US EPA data were self-reported monitoring results from facilities under the storm water general permit, which therefore suffer the same limitations in representativity and quality control as for the Los Angeles sample, described above. Consistency of sampling design and analytical methods, and quality control for analytical results, may be somewhat better because all data are from group applicants, who may have implemented similar methods and operated under some oversight. On the other hand, the sample of facilities was drawn from a nationwide pool, so facilities were subject to more variability in precipitation and other geographical factors than the Los Angeles sample. US EPA developed statistics for facility runoff concentration data reported prior to 1 January 1992, for a single year's monitoring results; therefore the data cannot be used to assess trends over time.

US EPA reported data for three metals plus eight conventional pollutants. Five of these are the same as constituents evaluated in the present research. US EPA reported mean, median, and upper fifth percentile concentration data assuming normal distribution. We compared these results to the same statistics for data from the Los Angeles sample, computed separately for each monitoring year. The comparison both serves to check validity of the Los Angeles sample results and investigates whether annual fluctuation in the monitoring results is significant in comparison to the magnitude of the measured concentrations.

We also compared our data to results reported by Line and colleagues [10]. Those data were acquired by a single research team, with well-controlled analytical quality and sampling protocols replicated across all facilities. Runoff samples were also controlled for collection time. Each sample was designed to capture the "first flush" of discharge from a given storm event. The researchers employed a rigorous method for selection of representative sampling points on each facility. All facilities were located in North Carolina, subject to relatively uniform climate, rainfall, and hydrogeologic conditions compared to the US EPA nationwide sample. Runoff samples were drawn from a single wet weather season, 1993–1994, and analyzed for concentration of eight metals and presence or absence of 10 organic substances.

The principal limitation to the Line data is the small number of facilities investigated. Data were limited to one field sample each from a total of 20 facilities, only two within the fabricated metal products industry (the same broad classification as the 100-plus facilities of the US EPA sample). It is not likely that data from two facilities are adequate to capture variability in concentration of pollutants generated by industrial activities that can vary widely within an industry sector. It is also not clear whether a single field sample, even when carefully chosen for spatial representativity and consistency of time within a given storm discharge, is representative of pollutants generated by changing conditions at a working industrial facility. However, these are the best-controlled industrial runoff concentration data of which the authors are aware, and are valuable for comparison to the present results.

2.3. Data analysis for regulatory decisions

Despite the limitations of the publicly-reported data, two forms of results describing industry sector characteristics were believed useful to support decisions about regulatory controls to protect the environment from pollutants in runoff from the metal plating sector. The first was the proportion of facilities reporting presence of a given constituent, particularly metals. That figure is some evidence to suggest which metals should be included among the mandatory-testing constituents specified for Sector AA in the Federal Multi-Sector Permit and for similar facilities in the California General Industrial Permit. The second was a parameter describing central tendency of the concentration data. An estimate of the typical concentration that can be expected from a given facility of this industry type can help in assessing relative concern with various constituents. The typical concentration may be compared to concentrations shown by other research to have some impact on human health or on organisms in the environment.

Our statistical analysis was limited by the representativity of the self-reported data, but was attempted to determine whether the method would be useful if the data were reliable. The authors do not suggest developing numerical discharge standards for facilities or for industry sectors based on global estimates of concentrations at which environmental impacts are observed. Such an approach would necessarily assume that concentration of pollutants in facility discharge correlates in some way to concentration experienced by organisms in the environment, an assumption not supported here. Effective policies to control environmental impacts should be based on estimates of total pollutant load from facilities in a specific watershed, and on characteristics of the receiving water. Those data are not available. The recommendation is that facilities' pollution prevention plans and regulators' enforcement activities should emphasize measures to control those constituents found at concentrations relatively high compared to concentrations impacting aquatic life at facilities where the constituents are reasonably likely to be present.

The central tendency parameter evaluated here was the median of each constituent concentration measured at facilities where the constituent was detected, that is, omitting non-detect occurrences from the computation. The median of detected occurrences for facilities in the Los Angeles sample was compared to three standards or objectives from regulatory requirements based on concentrations at which aquatic impacts are observed. The first standard was the Water Quality Objectives promulgated by the California Regional Water Quality Control Board, Los Angeles Region, in its Water Quality Control Plan (or Basin Plan) [20]. These are ambient water quality objectives intended to be protective of aquatic life in inland surface waters. The second was the US EPA's National Primary Drinking Water Standards Maximum Contaminant Limits (MCL) [21]. The third standard was the California Ocean Plan's Estimate of Chronic Toxicity (ECT) [22], ambient concentration water quality objectives for coastal ocean waters.

2.4. Trends in discharge characteristics within the sample

Three analyses were conducted on the monitoring reports' concentration data: proportion of facilities detecting each constituent; median concentration in facilities detecting each constituent; and direction of change in measured concentration at each facility. The three measures together are expected to help assess effectiveness of the regulations in reducing storm water pollutants; or, if such trends are not identifiable, to evaluate effectiveness of the monitoring data.

In assessing pollution prevention, concentration data are not the most effective measure. If BMPs were effective they would reduce the total mass of constituents discharged with storm water in a given year, presumably by reducing the annual total mass of pollutants generated on-site and left exposed to storm water. Concentration alone would poorly measure this in the absence of data on annual total precipitation, because even if long-term concentration values were steady or declined, total loads would vary greatly with total rainfall. Therefore, our trend analysis was conducted for 2 years with similar rainfall. With that restriction, concentration data would be a reasonably powerful indicator if the measured grab-sample runoff concentration reported under regulatory requirements reliably reflected the annual average concentration. The limitations in representativity and quality control described above are the principal limitations to the results, but the large sample of similar industrial facilities in a single geographic region makes this a more powerful analysis than available in any previous research.

About 685 mm (27 inches) of rain were measured at the Los Angeles Civic Center in water year 1993, and about 24 inches in water year 1995 [23]. Both were "wet" years, compared to the 120-year average for rain at the Los Angeles Civic Center of about 350 mm (14 inches). These 2 years are the most meaningful for comparison. (The middle year of the target period, water year 1994, recorded about 200 mm (8 inches) of rain, or about 67% of the long-term average.) As an added advantage, the 2-year interval is more likely to capture any reduction in pollutants from BMP implementation than a 1-year interval.

The first trend data analysis used the percent of monitoring events at a given facility in which each measured constituent was detected. If a substantial number of the sample facilities' pollution prevention efforts succeeded in eliminating use of a given substance for production, or completely avoiding that substance being exposed to storm water, then the proportion of non-detects would be expected to increase over the life of the General Industrial Permit. It is not known whether zero or very low discharge of any of these constituents is achievable by BMPs available to the metal finishing industry, so it is by no means certain the proportion of non-detects will increase even with diligent pollution prevention efforts. This analysis would identify such results if they were achieved.

The second analysis used the median concentration of each constituent for a second purpose. The central tendency of concentration for each constituent aggregated across all facility locations may be expected to decrease in years of similar rainfall if pollution prevention efforts were successful in at least some facility locations. As a potential confounding factor, the median of all detected values might increase if some facility locations reduced their discharges to below the detection limit. Those data points would then be excluded from the sample, leaving in the calculation only facilities with the higher, unchanged concentration values. Although this calculation is not a reliable indicator by itself, it is useful when considered along with the proportion of facilities where the constituent is detected.

The third analysis evaluated the direction of change, if any, in the reported annual concentration of selected constituents for each individual facility location. This analysis may be the most powerful of the three in detecting storm water pollution prevention among

R0025397

facilities of the sample. The relative concentration of measured constituents over time, in years of similar rainfall, may be a valid indicator of changing pollutant generation. Concentration may be expected to decrease at a given facility if its pollution prevention efforts are successful.

3. Results and discussion

Results fall into three categories: characterization of the industry, with comparison to previous research; central tendency data analysis to support potential regulatory discussions; and trends over time in the sample concentration data.

3.1. Comparisons to previously published data

Table 2 presents summary statistics for nine constituents. Of the 13 constituents evaluated, those four detected by fewer than four facilities in any of the 3 years are omitted in Table 2. Table 2 compares the concentration data for the Los Angeles metal plating facilities sample to similar data reported by US EPA [9], Line and colleagues [10], and the NURP studies [6].

Los Angeles metal finishers data included one high outlier each for chromium, copper, and nickel during 1994, and for zinc during 1995. Each of these was reported at an order of magnitude greater than any other data point for those constituents in any year. These were removed, assuming they may have been misreported or spurious results. Data for lead in the 1994 sample included one unusually high reading, about twice the magnitude of concentration reported at any other facility. This was not removed because the same facility reported high concentrations during all 3 years, so the data were assumed to reflect actual conditions at the facility, and therefore necessary to reflect variability of conditions in the sample. Decisions about which data points, if any, to censor are necessarily somewhat subjective, and clearly affect the resulting statistical analysis. This effect is another limiting factor in the use of the self-reported data.

Results of the US EPA analysis reported concentration data for five of the same constituents in its sample of 115 metal fabricating facilities. Reported concentrations were generally comparable to concentrations reported by the Los Angeles metal finishing facilities, considering the substantial variability among the three years of the Los Angeles data. Concentration of copper was somewhat lower in the Los Angeles metal finishers than the US EPA metal fabricators. O & G concentration was similar in the two studies, with the US EPA mean concentration bracketed by a highly variable set of Los Angeles data. (Overall mean concentration of reporting facilities in 1995 was about half the mean in 1993.) TSS mean concentration was somewhat lower in the Los Angeles facilities, ranging from about one-third to about one-half the US EPA facilities' mean. Reported concentration of lead was similar, though somewhat higher in the Los Angeles sample facilities, ranging from 20 to 80% higher than the mean of US EPA facilities. Concentration of zinc was also similar.

Median concentrations for the Los Angeles sample facilities were substantially lower than mean concentrations, most particularly for lead, TSS, and zinc. This is consistent with the occurrence of a few high-magnitude data points, as noted above, and as demonstrated by the high standard deviations for some parameters. This behavior was mirrored even more strongly in the US EPA data, where the standard deviation was not reported, but the median zinc concentration was about one-half the Los Angeles sample median while the mean concentration was nearly twice as high and the 95th percentile was higher by a factor of two to three.

The presence of a few high data points and a large number of non-detects argues that the data may be better fitted by a log-normal distribution, demonstrated to be a an accurate depiction for storm water pollutant data by researchers such as Driscoll et al. [24]. However, since US EPA and NURP data were reported assuming a normal distribution, the same assumption was used to calculate summary statistics of Table 2.

Comparison to data reported by Line et al. [10] for two North Carolina metal fabricating facilities showed the mean and median concentrations for the Los Angeles sample to be substantially higher, by an order of magnitude or more. Line et al. did not detect cadmium at either facility, suggesting that cadmium was not used at either location. Line et al. also did not detect O & G at either facility, to a reported detection limit of 5 μg/l, although that constituent was detected in more than 80% of the Los Angeles sample facilities each year, as noted below. This fact supports the observation that samples at two facilities are unlikely to be statistically representative of the range of characteristics in an industry sector.

Compared to NURP data for mean concentrations, the Los Angeles metal finishers sample mean concentrations were higher by about an order of magnitude for copper and zinc, and about equal for lead. This is not surprising given that NURP data are for urban catchments zoned for industrial land uses, not for specific facilities. Runoff from industries of multiple sectors, from transportation land uses, and from other activities may be expected to be lower in metals than metal fabrication facilities. The relatively high concentration for lead may reflect automotive activities. NURP data were somewhat higher in TSS, also to be expected if the catchment included more open space and more streets than the facility sampling data.

Table 2
Summary statistics for Los Angeles metal platers constituent concentration data (mg/l) compared to other research

	Los Angeles platers			EPA group applicants [12]		NURP [6]	Line [10]
	1993	1994	1995	Grab	Composite		
Mean							
Cd	0.07	0.08	0.12	–	–	–	< 0.004
Cr	0.24	0.17[a]	0.10	–	–	–	0.09
Cu	0.33	0.39[a]	0.39	0.63	0.46	0.04	0.04
Pb	0.13	0.20	0.16	0.11	0.06	0.18	0.07
Ni	0.16	0.26[a]	0.35	–	–	–	0.03
Zn	1.3	1.4	1.3[a]	4.2	2.2	0.2	0.92
O & G	10	9.2	4.9	6.1	–	–	< 0.005
TOC	19	29	26	–	–	–	–
TSS	100	81	65	190	130	180	0.04
Standard deviation							
Cd	0.15	0.18	0.26	–	–	–	–
Cr	0.28	0.17[a]	0.19	–	–	–	–
Cu	0.28	0.51[a]	0.37	–	–	–	–
Pb	0.27	0.32	0.25	–	–	–	–
Ni	0.24	0.33[a]	0.47	–	–	–	–
Zn	2.5	1.5	1.7[a]	–	–	–	–
O & G	59	14	6.5	–	–	–	–
TSS	260	160	170	–	–	–	–
TOC	32	40	35	–	–	–	–
95% ile							
Cd	0.41	0.41	0.66	–	–	–	–
Cr	0.76	0.75[a]	0.51	–	–	–	–
Cu	0.90	1.3[a]	0.87	4.3	0.64	–	–
Pb	0.83	0.71	0.80	0.89	0.22	–	–
Ni	1.2	0.85[a]	0.76	–	–	–	–
Zn	3.9	4.8	5.1[a]	9.8	11	–	–
O & G	18	43	16	21	–	–	–
TSS	430	450	200	760	420	–	–
TOC	79	76	82	–	–	–	–
Median							
Cd	0.00	0.00	0.00	–	–	–	< 0.004
Cr	0.15	0.00[a]	0.00	–	–	–	0.09
Cu	0.21	0.23[a]	0.33	0.03	0.02	–	0.04
Pb	0.00	0.00	0.00	0.00	0.00	–	0.07
Ni	0.00	0.14[a]	0.21	–	–	–	0.03
Zn	0.70	0.75	0.54[a]	0.36	0.21	–	0.92
O & G	1.4	3.6	2.6	2	–	–	< 0.005
TSS	100	81	65	76	32	–	0.40
TOC	5.2	17	12	–	–	–	–

Non-detects treated as zero concentration. See Table 3 for number of observations and number of non-detects in each sample.
[a] Sample censored to omit one high outlier point of questionable accuracy.

The usefulness of these data, based on assumed normal distributions and including zeros for non–detect events, is called into question by the substantial differences in central tendency concentration estimates between the US EPA nationwide sample and the Los Angeles sample, coupled with the substantial variation between years in the Los Angeles sample. It is likely that the selection of facilities in the sample has a strong influence on the magnitude of the calculated means. This is perhaps especially so for constituents where smaller proportions of facilities reported no detectable concentrations, and perhaps further exacerbated when comparing years of differing rainfall. Since the US EPA data encompass a much wider variability in rainfall, facility activities, and other factors, the nationwide sample of 115 facilities is suggested to be of marginal usefulness in predicting runoff concentrations for facilities of a particular region, for purposes such as estimating total load of constituents from a given watershed originating with a specific industrial sector.

3.2. Data analysis for regulatory decisions

The first analysis examined the proportion of metal plating facilities where storm water discharges were expected to contain measurable quantities of various constituents. The Los Angeles County self-reported monitoring data were analyzed to count the number of facilities testing for each constituent in which the constituent was detected. Table 3 shows the proportion of locations where each constituent was detected, for each of the 13 test constituents for which at least 10 facilities conducted analyses in any one year.

Of the 13 test constituents, four were identified in detectable concentrations by at least 80% of facilities in all three years, and are labeled "frequently detected" in Table 3. More than 95% of facility locations detected zinc in each of the 3 years, and between 80 and 90% of facilities detected copper. These results are not surprising. Zinc is widely detected in storm water discharges [17]. Copper is particularly widely used in metal plating activities, and O & G is present in detectable quantities in most industrial discharges. Total suspended solids (TSS) were reported at between 91 and 95% of locations, surprising only in that fewer than 100% of facilities identified soil sediments or particulates in detectable amounts. Of the four, only copper is not specified as a mandatory analyte either in the General Industrial Permit or the Multi-Sector Permit.

Five constituents were identified at between 25 and 75% of facilities in all 3 years, and are noted in Table 3 as "commonly detected." These included total organic carbon (TOC) and four metals: nickel, chromium, lead, and cadmium. TOC was present in detectable amounts at about two-thirds of locations in each of the 3 years. A significantly and consistently smaller proportion of facilities reported detecting TOC than reported detecting O & G.

None of the four metals is specified as mandatory-testing for facilities of Sector AA, and presumably for that reason a relatively small number of facility operators chose to test their samples for these substances. No more than 62 facilities, or fewer than one-half of the sample facilities, analyzed for any one of these metals in any year. However, they were widely found when tested for. In 1995 nickel and chromium were present at roughly two-thirds of facilities testing their discharges for these metals, and lead and cadmium were present at approximately one-third of facilities. This result suggests that those four metals may be commonly expected to be present in storm water discharges from metal plating facilities, and therefore that regulations might specify monitoring for the four metals at all metal plating facilities.

Table 3
Metal plating facility locations detecting constituents for each target year

		Number of locations tested			Percent detects		
		1993	1994	1995	1993	1994	1995
Frequently detected	Zinc	56	58	61	98	97	100
	TSS	129	123	137	96	95	91
	Copper	57	57	61	88	84	89
	O&G	109	115	119	82	100	85
Commonly detected	TOC	28	30	34	62	73	66
	Nickel	58	57	61	45	61	69
	Chromium	58	55	59	36	42	59
	Lead	44	58	62	32	47	39
	Cadmium	31	40	48	26	25	29
Seldom Detected	Silver	20	33	42	0	12	17
	Cyanide	13	28	35	8	25	14
	Mercury	18	4	9	11	0	11
	Arsenic	24	15	14	0	7	0

Substances detected at fewer than 25% of the locations include mercury, cyanide, silver and arsenic. These substances are widely recognized in the regulated community as highly toxic, capable of long-term health impacts and environmental damages if released even in small quantities, and subject to hazardous waste and toxic spill reporting regulations. It is not surprising that few facilities release these substances in quantities that would produce measurable amounts in storm water discharges.

The second analysis compared the median concentration of detects to relevant environmental standards. Table 4 shows the median of detected concentrations in each of the three years for the 13 test constituents. Table 4 also shows the Basin Plan objectives, the ECT, and the MCL for those constituents for which they have been promulgated. Table 4 shows the computed ratio of the 1995 median concentration of detects to each of the three standards, as a way to normalize the Los Angeles platers' runoff concentration for potential environmental and human health effects. Four constituents have notably high ratios: silver and copper as a proportion of ECT, which represents effects for aquatic life; and cadmium and lead for MCL, which represents effects of human exposure. Table 2, presented above, shows copper to be present at about 85 to 90% of facility locations at which the analysis was conducted; lead at about 30 to 45% of facilities; and cadmium at about 25 to 35%. This result suggests the three constituents should be strongly considered for mandatory monitoring in regulatory programs designed to protect receiving waters from pollutants in runoff from metal finishing facilities.

3.3. Trends in discharge characteristics within the sample

Data discussed in the previous sections were also used to assess trends in runoff constituents. The median concentrations in Table 4 for the two years of similar rainfall, 1993 and 1995, might be expected to decline if pollution prevention were highly effective at a large proportion of the sample facilities. That trend is mildly visible in TSS, zinc, and (to an even lesser extent) lead. The opposite trend is suggested in other constituents, most strongly in TOC, O & G, nickel, and chromium.

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Table 4
Los Angeles metal plating facilities concentration compared to health and environmental standards

	Median of detects (μg/l)			Basin plan[a] (μg/l)	1995 median as fraction of basin plan	ECT[b] (μg/l)	1995 median as fraction of ECT (%)	MCL[c] (μg/l)	1995 median as fraction of MCL (%)
	1993	1994	1995						
As	–[d]	–[d]	–[d]	50	n/a	19	n/a	50	n/a
Cd	250	260	300	10	30	8	38	5	60
Cr	200	300	350	50	7	18	19	100	3.5
Cu	300	260	370	–	n/a	5	74	1,300[e]	0.28
Pb	300	280	270	50	5	22	12	0[e]	Large
Hg	–[d]	–[d]	–[d]	2	n/a	0.4	n/a	2	n/a
Ni	200	330	380	–	n/a	48	8	100[a]	3.8
Ag	–[d]	300	280	50	6	3	93	–	n/a
Zn	700	750	570	–	n/a	51	11	–	n/a
Cyanide	–[d]	300	300	–	n/a	10	30	200[e]	1.5
O&G	3350	6080	4950	–	n/a	–	n/a	–	n/a
TOC	8950	16,500	15,000	–	n/a	–	n/a	–	n/a
TSS	43,800	23,000	23,000	–	n/a	–	n/a	–	n/a

[a] Water quality objective for aquatic life, Los Angeles Region Basin Plan, CRWQCB (1994).
[b] Estimate of chronic toxicity, California Ocean Plan, CSWRCB (1997).
[c] Maximum contaminant limit, national primary drinking water standards, USEPA (1996).
[d] Concentration data not included: substances detected by fewer than four facilities conducting analyses in both 1993 and 1995.
[e] Maximum contaminant limit goal, for substances where MCL has not been promulgated.

The increased median concentrations may signal ineffectiveness of any pollution prevention efforts, or may be caused by confounding factors. For instance, the samples included an increased number of facilities reporting data for metals, including new facilities in the sample each year where facility operators expected those metals to be present. This analysis may be useful over the long term, as pollution prevention becomes widely practiced, but in the early stages of the General Industrial Permit may be insufficiently powerful to detect pollution prevention achievements by individual facilities. Pollutant reductions of a small magnitude may be masked in this aggregate statistic by natural variability in constituent concentration and changing sample composition as compliance improves.

A companion analysis in Table 3 is the proportion of locations where each constituent was detected for the two years of similar rainfall. If the hypothesized improvement in pollution prevention over time were present in these facilities, Table 3 results might show a decreasing proportion of facilities where constituents are detected. Comparing percent detects for 1993 and 1995 in Table 3 shows a small reduction over time for TSS; increases of more than 20% for nickel and chromium; an increase of 7% for lead; and increases of 1 to 4% percent for zinc, copper, O & G, TOC, and cadmium. The substantial increases for nickel, chromium, and lead are probably attributable to increased testing for those metals among facilities where operators judge they are likely to be present—in other words, increased compliance effectiveness—while other facilities elect not to test, also permissible under permit requirements.

This approach, like the other aggregate data analysis method used, may be unable to detect pollution prevention accomplishments given the limitations of the sample and the data. Further, it is not clear that currently available pollution prevention measures are capable of achieving zero or very low discharge concentrations for these constituents. A data assessment of this form, conducted over several years as compliance increases and additional data become available, may be one way of determining whether some facilities can essentially eliminate any of these constituents from their runoff.

Evaluation of data on a facility-specific basis may be more effective at detecting pollution prevention achievements than the two aggregate measurements described above. That is the rationale for our third analysis, using the data to evaluate the change in concentration of measured constituents at the individual sample facilities for the years 1993 to 1995. This result should show a reduction in concentration over time at any facility where storm water pollution prevention efforts were effective over this period.

Table 5 shows the number of facility locations reporting pollutant concentration changes, categorized by direction of change for each of the constituents. Fig. 1 graphs the relative proportion of facilities where concentration increased and those where concentration decreased for eight constituents for which a large number of facilities conducted analyses during both 1993 and 1995. Pairs of data where the constituent was tested for but not detected are included in the "little or no change" category of Table 5. The expected trend was

Table 5
Trends in concentration of measured constituents at Los Angeles sample of metal plating facilities, 1993 to 1995

	Number of facilities			Proportion of facilities		
	Decrease	Increase	Little or no change[a]	Decrease	Increase	Little or no change[a]
Metals						
Arsenic[b]	0	0	11	0.00	0.00	1.00
Cadmium[b]	2	2	9	0.15	0.15	0.69
Chromium	5	10	10	0.20	0.40	0.40
Copper	6	12	5	0.26	0.52	0.22
Lead	2	8	11	0.10	0.38	0.52
Mercury[b]	2	1	4	0.29	0.14	0.57
Nickel	5	8	8	0.24	0.38	0.38
Silver[b]	0	0	10	0.00	0.00	1.00
Zinc	3	17	6	0.12	0.65	0.23
Other constituents						
Cyanide[b]	1	0	7	0.13	0.00	0.88
O&G	15	35	10	0.25	0.58	0.17
TOC	5	8	0	0.38	0.62	0.00
TSS	21	35	13	0.30	0.51	0.19

Research for each constituent are limited to the number of facilities testing for that constituent during both years of the comparison.

[a] Includes facility locations where constituent was tested for but not detected in both 1993 and 1995, and locations where change was less than 30% of median of detects for 1995.

[b] Small samples: fewer than five detects among facilities reporting analytical results for both years.

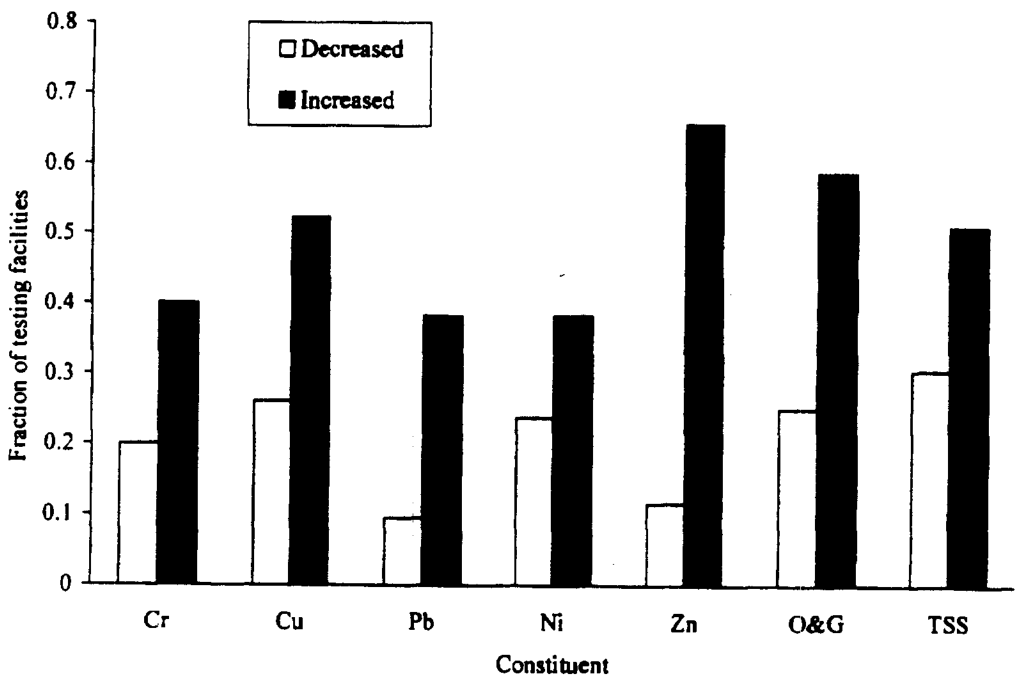

Fig. 1. Proportion of facility locations where constituent concentration decreased versus increased.

not observed. Remarkably, the opposite trend is apparent: measured concentration in runoff increased over the 2-year period for more facilities than those where it decreased, for every one of the eight constituents with at least five data points to compare.

Any of a number of confounding factors may account for this. The self-reported monitoring data may fail to capture full natural variability among storm discharges. Data variability caused by inconsistency and inadequate quality control among multiple regulated facilities may obscure any meaningful trends. Changes in concentration achieved by pollution prevention efforts may be small compared to baseline or background concentrations and to natural variability. Implementation of pollution prevention activities by the metal plating industry sector during the permit's initial 3-year period may be incomplete, or the measures chosen may be ineffective. Changing economic activity may have caused an increase in production over the target period, with a commensurate increase in pollutant-generating industrial activities at the sample facilities. Pre-existing contaminants at a facility may not be adequately removed, contained, or washed through the system. The presence of such a consistent pattern for all constituents strongly suggests the presence of some systematic confounding influence sufficiently powerful to mask any pollution prevention achieved by this sample of facilities during the first two years of BMPs specified under regulatory requirements.

Runoff constituent data reported by facilities under monitoring requirements of the current regulatory structure were found inadequate to support meaningful analyses of facility conditions or progress. Regulations requiring those data to be collected and reported affect a large number of businesses throughout the US, on the order of tens of thousands of facilities in California alone. The data are intended for multiple purposes beyond the assessment of regulatory effectiveness attempted here, such as alerting facility operators to changing conditions they should address with BMPs. However, if US EPA or state agencies intend to monitor progress by industrial sectors as a whole, they should consider more complete and better-controlled studies for more pollutants of concern, perhaps for a smaller number of facilities. More complete evaluations would capture variability at a given facility across entire wet weather seasons; and would correlate results with ancillary factors such as timing of rainfall, type of industrial activities at a facility, facility production rate, and BMPs implemented. Better-controlled studies would ensure consistent sampling techniques and quality control procedures at all facilities, and would limit the facility group to geographic areas of similar environmental and institutional conditions.

4. Conclusions

Storm water runoff quality is known to vary widely among industrial categories, and among facilities of similar types. Runoff chemical composition characteristics are not currently well understood, and improved understanding is critical to ongoing efforts to protect waters of the US from possible impacts by pollutants discharged with storm water associated with industrial activities. This research evaluated water quality data reported by metal finishing facilities in Los Angeles County, CA, as required under regulations pursuant to the US Clean Water Act. Similar data are being acquired and reported nationwide. These results are an initial attempt to systematically evaluate those data, and use the data to evaluate the effectiveness of the regulations and the potential impact of industrial activities on water quality in surface waters of the US. Important limitations to the data limit the conclusions that may be reached. Conclusions fall into three main areas.

First, data on runoff concentration of constituents in a US EPA analysis of metal products fabricating facilities appear roughly comparable to runoff concentration data reported by the sample of metal plating facilities in Los Angeles County that comply with field sampling, analysis, and monitoring reporting requirements of the California General Industrial Permit. The US EPA data have been previously presented as an initial screening estimate of pollutant concentration to be expected in runoff from facilities of particular industrial sectors. The variability of statistical treatments of the runoff constituent concentrations across three years in the Los Angeles sample, coupled with the variability in conditions of the nationwide sample of facilities reporting to US EPA, calls into question the validity of those data for planning purposes in developing control strategies for a given watershed or urban center. It is possible that a better prediction of expected concentration for planning purposes would be obtained using central tendency of detected data points only, in combination with estimated proportion of facilities where a constituent is detected. Alternately, an improved method for handling non-detect data might be considered.

Second, a number of potentially toxic metals widely detected in runoff from the sample facilities are not specified for required testing by state or federal regulations. The proportion of facilities detecting specific pollutants was relatively consistent for each of the three years' monitoring data evaluated, suggesting this statistic is among the more reliable among this paper's analyses. Zinc and copper were identified in 80% or more of the facility locations in the sample. Metals identified by more than 25% of the locations, but fewer than 75%, were nickel, chromium, lead, and cadmium. Fewer than 25% of the locations detected mercury, silver, cyanide, or arsenic, all substances with known highly toxic properties and all controlled under federal, state, and local regulations that reduce the likelihood of discharge to surfaces contacted by storm water. These conclusions should be tested by similar evaluations of the same industry sector in other regions, after accounting for possible regional variation in activities conducted at metal plating facilities.

Third, the self-reported runoff constituent concentration data currently available did not reveal any systematic progress in pollution prevention by the selected industry sector in a given region using any of the three analysis methods attempted here. Indeed, the data collected may not be adequate for such an assessment. That evaluation was one of the stated intentions of the regulatory requirement that facilities collect and report monitoring data. It is suggested that any pollution prevention achieved in the early years of the regulatory controls may be too small to discern against "background" variability using aggregate measures, such as central tendency of concentration and proportion of monitoring facilities detecting the constituents. A facility-specific analysis, intended to overcome these limitations, also failed to detect a trend toward pollution prevention, and in fact suggests the opposite trend, a systematic increase in concentration of constituents in monitored storm water discharges in the two years of similar rainfall. We could not determine whether this effect was due to incomplete or inadequate pollution prevention efforts by the regulated community; masking of long-term pollutant discharge trends by natural variability in the many factors affecting measured runoff constituent concentration; inadequacies in the self-reported monitoring data; or some combination of factors. Future research should apply methods presented here to incorporate additional monitoring data as it becomes available in future years. Detection of such trends may require more carefully designed and controlled monitoring of selected samples of industrial facilities, and may require observation periods substantially longer than the three years available here.

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FINAL REPORT

- TOXICITY TESTING
- STORMWATER
- TIME SCALES
- COMBINED SEWER OVERFLOWS
- IMPACT ASSESSMENT
- BIOLOGICAL TEST SYSTEMS

WATERSHED MANAGEMENT

A Framework for Assessing Time-Scale Effects of Wet Weather Discharges

WET WEATHER

PROJECT 92-BAR-1

Water Environment Research Foundation

1998

ABSTRACT

Wet weather discharges are a major cause of impacts on surface waters, and their effective management has become a high priority. Addressing wet weather toxic impacts requires comprehensive and robust assessment of their effects. However, toxicity assessment requirements for wet weather events differ markedly from those for continuous flow discharges. The intermittent nature of wet weather discharges means that time scales of exposure are a key element in selecting test systems. This study provides a framework for assessing wet weather discharge effects, and it recognizes that a time scale of response approach (rather than the traditional organism-based approach) is required for selecting toxicity tests. In this approach, the time-scale characteristics of response, independent of the test organism, are the main criteria for selecting toxicity tests. This approach and associated test system selection procedures formed the basis for developing an impact assessment protocol for wet weather discharges. The protocol starts with a design specification, addressing specific questions related to general program objectives. Primary design elements consider sampling location and sampling frequency. Collected samples are subjected to a time-scale toxicity analysis appropriate to one of three time scales of differing duration (intra-event, event, and long-term) defined in this project. Toxicity testing follows a tiered approach, moving from basic to advanced screening and, if necessary, to confirmatory testing. The protocol is designed to be an integral part of the Water Environment Research Foundation's Framework for a Watershed Management Program.

The lack of appropriate methods to measure intra-event toxicity has led to the modification of existing tests to provide systems that more closely reflect storm event conditions. Information generated in laboratory and field studies conducted at different locations in the United States have been used to facilitate the design of wet weather event assessment programs.

WATER ENVIRONMENT
RESEARCH FOUNDATION

A FRAMEWORK FOR ASSESSING TIME-SCALE EFFECTS OF WET WEATHER DISCHARGES

PROJECT 92-BAR-1

1998

by

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ENVIRONMENTAL STEWARDSHIP THROUGH
INNOVATIVE SCIENCE AND TECHNOLOGY

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BENEFITS

- Provides a tiered protocol for assessing the effects of wet weather events on receiving water ecosystems;

- Reviews literature associated with the effects of episodic exposure on receiving system biota and ecosystems and evaluates available tests for wet weather discharge impact assessment;

- Modifies standard test methodologies to produce a battery of complementary tests that are appropriate for wet weather event time-scale toxicity assessment;

- Provides a predictive tool for wet weather impact assessment based upon a simple conceptual model developed from hydrograph characteristics and contaminant concentration data;

- Demonstrates that continuous physicochemical and stage monitoring before, during, and after storm events is a key element of any wet weather discharge monitoring program; and

- Addresses variability of exposure during wet weather events and calculates an event toxicity unit (ETU), which provides an estimate of the toxicity of the event as a whole.

TABLE OF CONTENTS

ACKNOWLEDGMENTS III
BENEFITS V
LIST OF TABLES XV
LIST OF FIGURES XIX

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION

1.1 Introduction to the Project 1-1
1.2 Analysis of Existing Approaches and Issues 1-3
1.3 Report Organization 1-4

2.0 TIME-SCALE ISSUES

2.1 Introduction 2-1
2.2 Time-Scale Issues in the Physical/Chemical Analysis of the Environment 2-1
2.3 A Time-Scale Framework for Wet Weather Event Assessment—Hydrology 2-3
2.3.1 Introduction 2-3
2.3.2 Summary 2-4
2.4 A Time-Scale Framework for Wet Weather Event Assessment—Toxicity/Biology/Ecology 2-4
2.5 A Time-Scale Framework for Wet Weather Event Assessment—Ecology 2-8
2.5.1 Seasonal Effects 2-8
2.5.2 Habitat 2-9
2.6 A Time-Scale Framework for Wet Weather Event Assessment—Watershed and Drainage System Location 2-9

3.0 PROTOCOL FOR TIME-SCALE TOXICITY ASSESSMENT

3.1 Introduction 3-1

TABLE OF CONTENTS, CONT.

3.2 Sampling Location	3-3
3.3 Sampling Frequency	3-3
3.4 Biological Tier Testing	3-6
3.4.1 Test Tiers	3-6
3.4.2 Test Time Scales	3-7
3.4.3 Classification of Toxicity	3-7
3.5 Protocol Integration in Watershed Analysis	3-10
3.5.1 Introduction	3-10
3.5.2 Connecting to the WERF Watershed Management Strategy	3-12

4.0 BIOLOGICAL TEST SYSTEMS FOR TIME-SCALE TOXICITY ANALYSIS

4.1 Introduction	4-1
4.2 Biological Test Systems with Potential for Wet Weather Event Assessment	4-1
4.3 Test Selection Criteria	4-4
4.4 Evaluation of Test System Suitability for Wet Weather Event Assessment	4-6
4.5 Detailed Test System Selection Methodology	4-9
4.5.1 Introduction	4-9
4.5.2 Score Bandings for Test Selection Criteria	4-10
4.5.3 Weightings	4-10
4.6 Example Application of Test System Selection Methodology	4-15

5.0 SUMMARY INFORMATION ON METHOD DEVELOPMENT AND APPLICATION

5.1 Introduction	5-1
5.2 Time-Scale Toxicity	5-2
5.2.1 Introduction	5-2
5.2.2 PE-LET_{50}	5-3
5.2.2.1 Determination	5-3
5.2.2.2 Application	5-4
5.2.3 Event Toxicity Unit	5-5
5.2.3.1 Determination	5-5
5.2.3.2 Application	5-7

TABLE OF CONTENTS, CONT.

5.3 Basic Screening Test Evaluation 5-8
- 5.3.1 Introduction 5-8
- 5.3.2 *Ceriodaphnia dubia* IQ Test 5-8
- 5.3.3 Microtox Assay 5-9

5.4 Advanced Screening Tools 5-9
- 5.4.1 Introduction 5-9
- 5.4.2 Watershed Modeling—Storm Sewer Model 5-10
- 5.4.3 Toxicity Modeling 5-11
  - 5.4.3.1 Introduction 5-11
  - 5.4.3.2 Hydrograph-Based Toxicity Model 5-12
  - 5.4.3.3 Organism-Based Toxicity Model 5-13

6.0 STUDY SITE SUMMARY INFORMATION

6.1 Introduction 6-1

6.2 Copper Slough Watershed 6-1
- 6.2.1 STP Study Locations 6-3
- 6.2.2 The Kaufman Lake Storm Sewer System 6-3

6.3 Trinity River (Fort Worth) Watershed 6-4
- 6.3.1 Cra 6-13
- 6.3.2 Eastern Hills 6-13
- 6.3.3 Pylon 6-13
- 6.3.4 Sycamore Creek 6-14

6.4 Cuyahoga River (Cleveland) Watershed 6-14

7.0 LABORATORY-BASED STORM EVENT ANALYSIS

7.1 Introduction 7-1

7.2 Where Do I Start? 7-1

7.3 Analysis Design Questions 7-2
- 7.3.1 Where Do I Sample? 7-2
- 7.3.2 What Do I Sample? 7-3
- 7.3.3 When Do I Sample? 7-4

TABLE OF CONTENTS, CONT.

7.3.4 What Constitutes a Reference Sample? 7-4
7.3.5 How Can Toxicity Change Through a Storm Event? 7-5
7.3.6 How Do I Design a Sampling Program to Identify/Separate Water Column/Sediment Effects? 7-7
7.4 Test System Questions 7-8
7.4.1 What Is the Best Test System for Toxicity Analysis? 7-8
7.4.2 What is a Basic Screening Test and When Should I Use One? 7-9
7.4.3 What is an Advanced Screening Test and When Should I Use One? 7-9
7.4.4 What is a Confirmatory Test and When Do I Use One? 7-10
7.4.5 What are the Characteristics of an Optimal Test Battery for Storm Event Analysis? 7-10
7.4.6 What is the Optimum Screening Test Battery for Analyzing Intra-Event Toxicity? 7-10
7.4.7 What is the Optimal Screening Test Battery for Analyzing Event Toxicity 7-11
7.4.8 When Do I Need to Conduct Sediment Toxicity Testing? 7-12
7.5 Sampling Questions 7-12
7.5.1 When and Where Should I Sample to Determine Intra-Event, Event, and/or Long-Term Toxicity in a Watershed? 7-12
7.5.2 How Long Can I Store a Sample? 7-12
7.5.3 How Much Sample Should I Collect? 7-16
7.5.4 What Should I Expect Sampling and Analysis to Cost? 7-16
7.5.5 Where Should I Sample in a Sewer System, in Relation to an Outfall, or in a Drainage Network? 7-17
7.5.6 When and How Should I Collect Composite Samples? 7-17
7.6 Wet Weather Toxicity Questions 7-20
7.6.1 How Do I Characterize Intra-Event, Event, and/or Long-Term Toxicity? (Effect vs. Impact) 7-20
7.6.2 How Many and What Type of Events Should I Sample to Characterize Toxicity? 7-21
7.6.3 What Happens to Toxicity in Closely Spaced Events? 7-22
7.6.4 Are There Some Events that Should Not Be Sampled? 7-22
7.6.5 What is the Toxicity Associated with Rainwater? 7-22
7.7 Water Quality Questions 7-23
7.7.1 Where Do I Sample to Adequately Assess Water Quality? 7-23

R0025415

TABLE OF CONTENTS, CONT.

7.7.2	Do I Need to Sample for Water Quality when the Objective of the Analysis is Toxicity Assessment?	7-23
7.7.3	Why is Continuous Monitoring of Some Parameters Essential?	7-24
7.7.4	What Water Quality Changes are Typical of Storm Events and How are These Related to Changes in Toxicity?	7-24
7.8	Sources Questions	7-24
7.8.1	Must I Do Anything Special to Sample or Analyze for CSO/SSO/Urban Runoff Effects?	7-24
7.8.2	What Do I Need to Know About a Watershed to Identify Sources?	7-25
7.8.3	How Do I Identify the Source of an Observed Effect?	7-25
7.9	Interpretation and Analysis Questions	7-25
7.9.1	How Do I Interpret the Data from Basic Screening Tests?	7-25
7.9.2	How Do I Decide from Basic Screening Test Data If a Discharge is Toxic?	7-26
7.9.3	How Do I Use Intra-Event Analysis to Identify Where Toxicity Occurs in a Storm?	7-26
7.9.4	How Do I Classify Discharges on the Basis of Basic Screening Test Data?	7-26
7.9.5	What Course of Action Should Be Followed for Discharges Showing No Toxicity in Basic Screening Tests?	7-28
7.9.6	What Course of Action Should Be Followed for Discharges Showing Moderate or High Toxicity in Basic Screening Tests?	7-29
7.9.7	How Do I Use Advanced Screening Tests to Clarify the Extent of Toxicity Measured in Basic Screening Tests?	7-29
7.9.8	How Do I Use Advanced Screening to Identify the Cause of Toxicity?	7-30
7.9.9	How Do I Separate Wet Weather Effects from Other Watershed Influences in Receiving Water Samples?	7-31
7.9.10	What is the Relationship of Wet Weather Toxicity to Dry Weather/Baseline Flow Toxicity?	7-32
7.9.11	Does Toxicity Vary Seasonally?	7-33
7.9.12	Does Toxicity Vary by Location within the Watershed?	7-33
7.9.13	Does Toxicity Vary by Region?	7-34

TABLE OF CONTENTS, CONT.

8.0 FIELD-BASED STORM EVENT ANALYSIS

8.1 Assessment Design Questions 8-1
- 8.1.1 When Do I Use In Situ Tests or Biosurveys? 8-1
- 8.1.2 When Shall I Perform an In Situ Test as Opposed to a Biosurvey? 8-2
- 8.1.3 Where Shall I Deploy In Situ Tests or Conduct Biosurveys? 8-2
- 8.1.4 What Constitutes a Reference Site? 8-3
- 8.1.5 What Action Should I Take if a Suitable Reference Site Cannot Be Identified and Sampled? 8-4
- 8.1.6 When and Where Are Sediment Analysis/Assessment Efforts Needed? 8-4

8.2 Sampling Questions 8-5
- 8.2.1 How Many Measurements Must I Take? 8-5
- 8.2.2 How Much Do Field Assessments Cost? 8-5
- 8.2.3 Are Unique Devices Needed to Perform In Situ Testing or Biosurveys? 8-6
- 8.2.4 Which Organisms are Best for Field-Based Wet Weather Analysis? 8-7
- 8.2.5 How Long Should I Expect to Maintain a Sampling Program to Assess Effect? 8-7

8.3 Sources Questions 8-7
- 8.3.1 Do I Use Different Techniques for Different Sources? 8-7
- 8.3.2 What Must I Know about Sources to Effectively Develop a Field Analysis Program? 8-8
- 8.3.3 How Do I Separate/Compare the Effects of Multiple Sources in a Field Analysis Program? 8-8

8.4 Wet Weather Event Questions 8-8
- 8.4.1 When and How Do I Use In Situ or Biosurvey Techniques for Event, Multiple Event, and/or Long-Term Analysis? 8-8
  - 8.4.1.1 In Situ Tests 8-8
  - 8.4.1.2 Biosurvey Techniques 8-10

8.5 Water Quality Questions 8-13
- 8.5.1 What is the Relationship between Water Quality and Sediment Quality? 8-13
- 8.5.2 Where and When Do I Sample Water Quality to Support In Situ Testing? 8-14

8.6 Test System/Assessment Procedure Questions 8-15
- 8.6.1 What Is the Best In Situ Test System? 8-15
- 8.6.2 What Is the Best Biosurvey Procedure? 8-15

TABLE OF CONTENTS, CONT.

8.6.2.1 Rapid Bioassessment Protocol I—Benthic Macroinvertebrates and Rapid Bioassessment Protocol IV—Fish 8-16
8.6.2.2 Rapid Bioassessment Protocol II—Benthic Macroinvertebrates 8-16
8.6.2.3 Rapid Bioassessment Protocol III—Benthic Macroinvertebrates and Rapid Bioassessment Protocol V—Fish 8-16
8.6.3 Do I Use Different Tests in Different Regions? 8-16
8.6.4 Should I Use Indigenous Organisms as a Test System? 8-17
8.6.5 What Must I Do to Successfully Deploy Common Laboratory Species, such as *Ceriodaphnia*, *Hyalella*, etc., in In Situ Test Systems? 8-17
8.6.6 Are There Special Procedures—Water Quality or Toxicity Analyses—Supporting Certain Test Systems? 8-17
8.7 Interpretation and Analysis Questions 8-18
8.7.1 What Does an In Situ Test Mortality Really Mean? 8-18
8.7.2 How Should I Analyze Field Data? Must I Identify Species? Which Water Quality Index Is Appropriate for Wet Weather Event of BMP Effect Analysis? 8-18
8.7.2.1 Structure 8-19
8.7.2.2 Function 8-20
8.7.3 How Do I Conduct Sample-Specific Analyses? (What Information Should I Extract from a Sample?) 8-21
8.7.4 How Do I Compare Samples from Different Sites or Different Times? 8-23
8.7.4.1 Differences or Similarity 8-23
8.7.4.2 Binary Data 8-23
8.7.4.3 Quantitative Data 8-24
8.7.4.4 Cluster Analysis and Ordination 8-24
8.7.4.5 Rank Comparisons and Correlations 8-25
8.7.5 What Do I Do if In Situ Tests Disagree with Laboratory Testing Results? 8-25

9.0 CONCLUSIONS

10.0 FUTURE RESEARCH

R0025418

TABLE OF CONTENTS, CONT.

APPENDIX A	A-1
APPENDIX B	B-1
APPENDIX C	C-1
REFERENCES	R-1
PUBLICATION ORDER FORM	
WERF SUBSCRIBERS	

LIST OF TABLES

2-1	Summary of Watershed Analysis	2-4
2-2	Example Measurements Used to Apply the Time-Scale Concept	2-8
3-1	Defining Sampling Location	3-4
3-2	Defining Sampling Frequency	3-5
3-3	Defining Biological Testing Tiers	3-6
3-4	Defining Biological Testing Time Scale	3-8
3-5	Scheme Proposed for Classifying Wet Weather Event Toxicity	3-11
4-1	Test Systems for Wet Weather Event Assessment	4-3
4-2	Level of Importance of Test Selection Criteria for Different Time Scales	4-6
4-3	Evaluation of Bacterial Bioluminescence According to Selection Criteria	4-7
4-4	Preliminary Assessment of Test Suitability for Time-Scale Application	4-8
4-5	Score Bandings for Intra-Event Time-Scale Test Selection Criteria	4-11
4-6	Score Bandings for Event Time-Scale Test Selection Criteria	4-12
4-7	Score Bandings for Long-Term Time-Scale Test Selection Criteria	4-13
4-8	Weighting Factors for Intra-Event Test Selection Criteria	4-14
4-9	Weighted Scores for Candidate Basic Screening Test Systems for Intra-Event Time-Scale Assessment	4-16
5-1	Differences Between Continuous and Episodic Event Assessment Approaches	5-2
5-2	Summary of Supplemental Time-Scale Toxicity Experiments Performed	5-4
5-3	Comparison of PE-LET$_{50}$ Metric to Other Metrics in Use or Proposed for Use	5-5
6-1	Summary of 1994 Storm Events Monitored in the Copper Slough Watershed (US and DS Stations)	6-6
6-2	Summary of 1995 Storm Events Monitored in the Copper Slough Watershed (US and DS Stations)	6-7
6-3	Summary of the Storm Event Monitored at the Kaufman Lake Storm Sewer (Copper Slough Watershed)	6-8
6-4	Summary of Toxicity Data for Water Samples Taken from Receiving Water Locations at the Kaufman Lake System	6-11
6-5	Summary of the Storm Event Monitored at Locations on the Trinity River Watershed	6-12
7-1	Comparative Data for the Microtox and *C. dubia* IQ Tests for Stormwater Samples	7-13
7-2	Microtox Responses Measured in Undiluted Stormwater Samples Taken at Various Los Angeles River Locations (after Raco, 1988)	7-13

LIST OF TABLES, CONT.

7-3	Factors for Determining Time Scale of Toxicity Testing	7-14
7-4	Summary of the Repeat Tests on Stormwater Samples Using Basic Screening Tests	7-15
7-5	Summary of Statistical Analyses of Repeated Tests on Stormwater Samples	7-15
7-6	Volume of Sample Required for Different Types of Toxicity and Chemical Analysis	7-16
7-7	Toxicity Analyses of Discrete Samples and Build-Up of Composite Samples	7-19
7-8	Toxicity Analyses of Composite Samples	7-19
7-9	Invertebrate Taxa at KLSS Upstream and Downstream Sites at Beginning and End of Intensive Campaign	7-21
7-10	Microtox and *C. dubia* IQ Data for Intra-Event Analysis of Different Storms at Various Locations and Resulting Classifications	7-28
7-11	*C. dubia* IQ Data from Concentration-Response Tests on Stormwater Samples from the 7/4/95 Storm at KLSS	7-30
7-12	Comparison of Maximum Microtox Responses during Storm Events with Measured Zinc Concentrations	7-31
7-12	Toxicity Data for Storm Event Samples Taken on 5/24/95 from Sites with Different Land Uses in Trinity River Watershed (Fort Worth)	7-34
8-1	Toxicity Data for In Situ Water Column Tests Deployed at KLSS for the 6/1/95 Storm	8-9
8-2	Toxicity Data for In Situ *H. azteca* Water Column and Sediment Tests	8-14
8-3	Toxicity Measured in *H. azteca* and *P. promelas* In Situ Tests Located in the Sun and Shade	8-18
8-4	Toxicity Data from Laboratory and In Situ Sediment Tests Using *D. magna* and *H. azteca*	8-26
A-1	Summary of Mean Time Between Storm Events for Kaskaskia Ditch	A-4
A-2	Number of Storm Events by Category and Year for Kaskaskia Ditch	A-5
A-3	Recession Coefficients for Storm Events in Kaskaskia Ditch	A-5
A-4	Base Flow and Storm Runoff Volume for January 3, 1993 Storm Using Straight Line, Fixed Base and Variable Slope Methods	A-6
A-5	Summary of Hydrograph Statistics for Copper Slough for October, 1991, to June, 1993	A-8
A-6	Summary of Mean Time between Storm Events for Johnson Creek	A-9
A-7	Number of Storm Events by Category and Year for Johnson Creek	A-9
A-8	Recession Coefficients for Storm Events in Johnson Creek	A-9
A-9	Summary of Mean Time between Storm Events for Cuyahoga River	A-10
A-10	Number of Storm Events by Category and Year for the Cuyahoga River	A-11

R0025421

LIST OF TABLES, CONT.

A-11	Recession Coefficients for Storm Events in the Cuyahoga River	A-11
A-12	Summary of Mean Time between Storm Events for Ware Creek	A-12
A-13	Number of Storm Events by Category and Year for Ware Creek	A-12
A-14	Recession Coefficients for Storm Events in Ware Creek	A-12
A-15	Summary of Mean Time Between Storm Events for the Trinity River	A-13
A-16	Number of Storm Events by Category and Year for the Trinity River	A-14
A-17	Recession Coefficients for Storm Events in the Trinity River	A-14
A-18	Summary of Mean Time between Storm Events for the Salt River	A-15
A-19	Number of Storm Events by Category and Year for the Salt River	A-15
A-20	Recession Coefficients for Storm Events in the Salt River	A-15
B-1	Summary of Supplemental Time-Scale Toxicity Experiments Performed	B-3
B-2	Percent Mortality of *H. azteca* at 48 hr after a 1.0-mg/L Cd Exposure	B-5
B-3	Comparison of PE-LET_{50} Metric with Other Used and Proposed Metrics	B-12
B-4	Summary of Ultimate PE-LET_{50} Values and Time after Exposure When Ultimate PE-LET_{50} Values Were Reached for UIUC Organisms	B-13
B-5	UIUC *C. dubia* 8-day Cumulative Mean Neonate Production	B-14
B-6	Mean Dry Weight of UIUC *P. promelas* 7 Days after Brief Cd Exposure	B-20
B-7	Chemical Characteristics of Dilution Waters Used	B-27
B-8	Example PE-LET_{50} Data for Event Toxicity Unit Analysis	B-29
B-9	LC_{50} Values for Samples from 5/24/96 Event at Cra Site	B-33
B-10	LC_{50} Values for Samples from 9/6/96 Event at Cleveland #35 Site	B-33
B-11	Summary of Hormesis by Contaminant and Temperature	B-37
B-12	Concentration Ranges of Stimulation by Contaminant and Temperature	B-38
B-13	Objectives of the Different Fractionation Steps in Toxicity Characterization	B-41
B-14	Schedule for Conducting Toxicity Characterization on the 1500 Sample from the 4/25/96 Storm at the Kaufman Lake Storm Sewer	B-42
B-15	Microtox Data for the Toxicity Characterization of the 1500 Sample from the 4/25/96 Storm at the Kaufman Lake Storm Sewer	B-46
C-1	Relationship of River Variables as Established by Time-Scale Perspective (After Schumm and Lichty, 1965)	C-5
C-2	Expected Spatial and Temporal Scales, Events, Processes, and Water Quality Issues (Modified from Frissell et al., 1986)	C-7

LIST OF FIGURES

3-1	Schematic Overview of Time-Scale Toxicity Test Application Protocol	3-2
4-1	Biological and Ecological Organization Hierarchies	4-2
5-1	Change in PE-LET$_{50}$ over Time for *H. azteca* Cd Exposure	5-6
5-2	Example Calculation of an Event Toxicity Unit (ETU)	5-7
5-3	Advanced Screening Tools	5-10
6-1	Copper Slough Watershed	6-2
6-2	Diagram of Kaufman Lake Sites	6-5
7-1	Times from Start of Storms to Observation of Peak Toxicity as Measured by the Microtox and *C. dubia* IQ Tests	7-8
7-2	Toxicity Data for the 7/14/95 Storm at KLSS	7-7
8-1	Summary of Biosurvey Data for Locations on the Copper Slough	8-11
A-1	Example Hydrograph from the Copper Slough, Champaign, IL, Providing an Illustration of Hydrograph Analysis for Base Flow Separation	A-3
B-1	Percent Immobility of UIUC *H. azteca* after 60-min Cd Exposure	B-4
B-2	PE-LET$_{50}$ Determination for *H. azteca* Exposed to 1.0-mg/L Cd	B-6
B-3	Change in PE-LET$_{50}$ over Time for UIUC *H. azteca* Cd Exposure	B-6
B-4	Change in PE-LET$_{50}$ over Time for UIUC *C. dubia* Cd Exposure	B-7
B-5	Change in PE-LET$_{50}$ over Time for UIUC *P. promelas* Cd Exposure	B-7
B-6	Percent Immobility of UIUC *H. azteca* as a Function of Exposure Time and Cd Concentration	B-8
B-7	Change in PE-LET$_{50}$ over Time for UIUC *H. azteca* Zn Exposure	B-9
B-8	Change in PE-LET$_{50}$ over Time for UIUC *C. dubia* Zn Exposure	B-10
B-9	Percent Immobility of UIUC *C. dubia* after 30 min Phenol Exposure	B-10
B-10	Cumulative Neonate Production of UIUC *C. dubia* after 240-min Cd Exposure	B-15
B-11	Percent Inhibition of UIUC *C. dubia* Galactosidase Enzyme after 120-min Cd Exposure	B-16
B-12	Percent Inhibition of UIUC *C. dubia* Galactosidase Enzyme after 15-min Cd Exposure	B-16
B-13	Maximum Percent Times and Exposure Concentrations of Cadmium	B-17
B-14	Recovery Time for Enzyme Activity of UIUC *C. dubia* after Brief Cd Exposures	B-17
B-15	Comparison of PE-LET$_{50}$ and LT$_{50}$ Values for UIUC *C. dubia* Cd Exposure	B-19

LIST OF FIGURES, CONT.

B-16	Comparison of PE-LET_{50} and LT_{50} Values for UIUC *C. dubia* Zn Exposure	B-21
B-17	Comparison of PE-LET_{50} and LT_{50} Values for UIUC *C. dubia* Phenol Exposure	B-22
B-18	Comparison of PE-LET_{50} Values for Different Species over a Range of Cd Concentrations	B-23
B-19	Comparison of PE-LET_{50} Values for Different Species over a Range of Cd Concentrations Normalized to 24-hr LC_{50} Values	B-23
B-20	Comparison of PE-LET_{50} Values for Different Species over a Range of Zn Concentrations	B-24
B-21	Comparison of PE-LET_{50} Values for Different Species over a Range of Zn Concentrations Normalized to 24-hr LC_{50} Values	B-25
B-22	Comparison of PE-LET_{50} Values for *C. dubia* Exposure to Various Toxicants	B-26
B-23	Comparison of PE-LET_{50} Values for *H. azteca* Exposure to Various Toxicants	B-26
B-24	Comparison of PE-LET_{50} Values for Different Stock Cultures over a Range of Cd Concentrations	B-27
B-25	Example Calculation of an Event Toxicity Unit (ETU)	B-30
B-26	1/PE-LET_{50} versus Time for 5/24/95 Storm Event at Cra	B-31
B-27	1/PE-LET_{50} versus Time for 9/6/96 Storm Event at Cleveland #35 Site	B-32
B-28	IQ Test Results with YCT Added to Test Solution	B-34
B-29	IQ Test Results with Kaolinite Added to Test Solution	B-34
B-30	IQ Results for Different Filtering Methods	B-35
B-31	Microtox Assay Results for the July 4, 1995, Storm at Kaufman Lake Storm Sewer	B-37
B-32	Test Battery Results for the July 4, 1995, Storm at Kaufman Lake Storm Sewer	B-38
B-33	Flow Chart for Toxicity Reduction Evaluations	B-40
B-34	TIE Procedure for Stormwater Samples	B-43
B-35	TIE Procedure for Reference Water Samples	B-44
B-36	Example Hydrograph, Illustrating Rising and Falling Limbs	B-47
B-37	Example of Methods Used to Define Recession Constants for Storm Hydrograph	B-49
B-38	Expected Changes in Contaminant Concentration with Discharge; B and C Are Expected Changes Due to Single Storm Events	B-51
B-39	Example TU Prediction for a Two-Peak Storm	B-52
B-40	One-Compartment Organism Representation Used in Some First-Order Kinetics Models	B-52

LIST OF FIGURES, CONT.

B-41	Curve Fitting to Obtain k_a/C_D and k_r Values from Experimental Data	B-55
B-42	Example of a Contaminant Concentration Profile	B-56
B-43	Calculated C_N/k_a Values for 10% and 50% Sensitivity Levels	B-57
B-44	PLTC Values for the 10% and 50% Sensitivity Levels	B-58
B-45	Population Mortality Predictions Based on PLTC Values	B-58
B-46	Predicted Total Zinc Accumulation in *Ceriodaphnia dubia* at Cra During the May 24, 1995, Storm	B-59
B-47	Results of Toxicity Test Battery for the May 24, 1995, Storm at Cra	B-61
B-48	Kaufman Lake Storm Sewer Watershed with Major Sewers Indicated	B-64
B-49	Estimated Hydrograph for a Two-Hour Storm	B-65
B-50	Predicted Hydrographs for the KLSS Outlet for Different Intensity Storms	B-65
C-1	Illustration of Distance Disturbance Paradigm, Coupling Spatial and Temporal Dimensions for Ecosystem Management	C-2

EXECUTIVE SUMMARY

Objectives

This report presents a summary of the research record developed for a project sponsored by the Water Environment Research Foundation (WERF) entitled, "Region Specific Time-Scale Toxicity in Aquatic Ecosystems." The project was initiated in September, 1993, with the following research objectives:

- Develop a database for frequency and duration of exposure for contaminants in combined sewer overflow (CSO) and stormwater runoff;
- Review the literature to identify biological test systems appropriate for use in detecting acute and chronic effects of CSO and stormwater discharges;
- Conduct a series of field studies to quantify the relationships between chemical toxicity and the frequency and duration of exposure of aquatic organisms to contaminants during wet weather discharges; and
- Develop an ecosystem-based management context for wet weather discharges that integrates the need for both regulatory criteria and the protection of ecosystem health.

An interim report, *Selecting Biological Test Systems to Assess Time Scale Toxicity,* was published by WERF to disseminate initial project findings (Objectives 1 and 2). Under the umbrella of Objective 3, the project team undertook literature reviews to quantify relationships between chemical toxicity and the frequency and duration of exposure–time-scale toxicity. Objective 4 of the research—to develop an ecological context for wet weather discharge assessment and management—is the subject of this report.

Background

To address time-scale toxicity, it is necessary to implement a comprehensive and robust assessment of the effects of wet weather discharges. To meet this goal, it is necessary to understand how test systems respond to wet weather discharge conditions and how to integrate assessments of direct toxicity with in-stream biosurveys and chemical analysis. Although methods for sampling and impact analysis of continuous flow effluents are well developed, and for the most part standardized, no standard methods exist to determine the effects of storm-related episodic exposure conditions common to wet weather discharge events. Furthermore, the direct toxicity assessment requirements for episodic wet weather events differ markedly from those for continuous flow discharges, such as standard Whole Effluent Toxicity (WET) testing, since the assumptions for the latter are inappropriate for some wet weather event analysis. The intermittent nature of wet weather discharges means that the time scales of exposure are a key element in analyzing the responses of test systems.

Protocol

Establishing a time scale for wet weather discharge assessments requires a careful analysis of program objectives, location, storm characteristics, sampling needs, and receiving system. Program objective issues set a time scale for analysis and are constrained by the time-scale characteristics of the receiving system/discharge combination, which is the subject of the analysis. The time scales identified in this research are: 1) intra-event, which addresses short-term variability in an event and encompasses time scales of seconds to hours, 2) event, which provides an integration of change that occurs during a single event and encompasses time scales of hours to days, depending on the type of storm, 3) long-term, which characterizes event differences and provides an integration of wet weather characteristics and encompasses time scales of days to months. Location issues include position in the watershed and the constraints a specific site places on hydrology, expected water quality, and ecology. Storm issues are seasonality, frequency, return period, and intensity class, all of which alter water quality expectations and affect short- and long-term concentration-duration relationships, defining toxicity and eventual receiving system impact. Sampling issues define the precision required in contaminant identification and the associated identification of concentration variability, characterize the dynamics of contaminants in treatment technologies (and eventually pipes and open channel flow), assist in the determination of contaminant fate, and establish time-scale bounds for biological effect analysis. Receiving system issues are associated with the physical, chemical, and biological/ecological characteristics of the receiving system, which combine to constrain the types of time-scale analysis that are needed, or even possible.

Time-Scale Definition. The intra-event, event and long-term time scales were determined based on analysis of a database of frequency and duration of exposure for water quality changes developed from literature analysis of time-related contaminant change in combined sewer overflow (CSO) and stormwater runoff. This research project characterized water quality change using continuous monitoring and time sequenced sampling for contaminant analysis. Chapter 2.0 and Appendix A summarize regional hydrologic characteristics to provide information on storm event characteristics to assist in defining storm events. This library provides a regional perspective on wet weather related flows, including the mean time between storms, categorization of storm events, and a hydrograph characterization of typical storm events. From this analysis of potential time-related contaminant change, a wet weather toxicity assessment approach was developed.

Time-Scale Toxicity. This approach recognized that current continuous discharge assessment methods were organism-based in that the time scale of exposure is defined by the life history or other characteristics of the test species. The research in this program adopted a time scale of response approach in which the time-scale characteristics of the response, independent of the organism producing that response, are the major criteria for selecting a toxicity testing procedure. Implementation of a time-scale of response approach, and associated test system selection procedures, form the basis of a receiving system impact assessment protocol for wet weather discharges, which is provided in Chapter 3.0 of this report. The protocol presented for the development of a wet weather toxicity assessment program uses information on the expected time-scale changes in concentration/duration exposure to select a test system that will adequately respond to the physical and chemical conditions associated with wet weather discharges both during and after an event.

Protocol Application. The protocol starts with a design specification developed from general program objectives and refined by study plans that address specific questions related to these objectives. Primary design elements consider sampling location and sample-collection frequency, defined by study objectives and location. Samples collected are then subjected to an appropriate time-scale toxicity analysis that follows a tier-testing approach. Tier testing is initiated with basic screening tests that establish the presence or absence of toxicity in wet weather event discharges, and allow a classification by degree and nature of toxicity. Advanced screening tests are then used to identify sources, characterize event toxicity to assist in defining an event toxic unit, and define effect characteristics to guide both short- and long-term assessments of receiving water impact. Based on the results of basic and advanced screening tests, analysis can continue to a confirmatory tier that determines or confirms actual effects in the receiving water ecosystem. Location issues were identified by this research as critical elements of the protocol. When selecting sampling locations for a wet weather discharge assessment, it should be recognized that while the nature of the location may define aspects of sampling frequency and biological or ecological test system validity there might also be feedback from sampling or testing issues used to set sampling locations. Three objective-related sampling location categories, in-pipe, receiving system - single discharge, and receiving system - multiple discharge, were identified and used to define sample frequency and test system application. The protocol for time-scale toxicity assessment is designed to be an integral part of the WERF Framework for a Watershed Management Program.

Selecting Biological Test Systems

Supporting the protocol, Chapter 4.0 presents an objective methodology for selecting biological test systems according to key test-selection criteria that are based on both wet weather event assessment and general test requirements. One criterion, relating to previous application to wet weather event assessment, stands alone but the remainder are grouped into categories of 1) time-scale issues, 2) measurement issues, 3) ecological relevance, and 4) cost. As part of this project, information on test systems was developed and summarized to provide a basis for scoring test systems in relation to criteria, and weightings based on levels of importance related to specific time scales of analysis. Chapter 4.0 provides a summary of applicable test systems and an example of test system selection.

Test System Development and Application

Chapter 5.0 and Appendix B summarize the development and/or application of a range of techniques used for, or in support of, basic and advanced screening methodologies that can be used for toxicity characterization, following the establishment of high or moderate toxicity in screening tests. The advanced screening methods described are 1) a toxicity identification evaluation (TIE) procedure, which allows identification of specific contaminant groups giving rise to toxicity in a sample, 2) a simple model that can be used to predict site-specific, receiving-system toxicity from hydrograph characteristics and expected chemical contaminants with known toxicity, 3) a toxicity prediction modeling approach for heavy metals based on empirical measures of wet weather event toxicity, and 4) a simple storm sewer drainage model that can be used for estimating storm hydrographs to define sampling requirements and assist in identifying sources of contaminants.

Regional Studies

Information on the study sites, and the storm event assessment information developed as a part of this research are provided in Chapter 6.0. Research focused on three field study sites. The main study site was the Copper Slough Watershed near Champaign, IL. Other locations used on the Trinity River Watershed in Ft Worth, Texas, and the Cuyahoga River Watershed at Cleveland, Ohio. In-pipe toxicity was assessed in storm water samples taken from the Kaufman Lake storm sewer on the Copper Slough watershed and three locations on the Trinity River watershed (Cra, Eastern Hills, and Pylon). Receiving waters were assessed in the Copper Slough, the Trinity River (Sycamore Creek), and Mill Creek on the Cuyahoga River. In total, over 50 storm events were assessed in this research.

In the 1994 campaign, fifteen storms were assessed from May through November, concentrating on Copper Slough watershed sites (upstream and downstream from a sewage treatment plant). In the 1995 campaign, two storms were assessed in Fort Worth, Texas, and one in Cleveland, Ohio. In addition, three storms were assessed at the Kaufman Lake Storm Sewer (KLSS) in the upper portion of the Copper Slough. In 1996, seven storms were assessed at the KLSS, including a comprehensive two-week campaign that sampled multiple storms and coordinated laboratory toxicity testing, in situ toxicity assessments, and biosurveys. An additional storm event in Fort Worth and a storm sequence in Cleveland were also assessed in 1996.

Critical Questions and Answers

The information developed from the literature reviews, modeling, field, and laboratory research was used in Chapters 7.0 and 8.0 to define and provide answers to questions, which users should ask when designing wet weather event assessment programs. These chapters also provide relevant information and answers using information generated in the study for the field sites described in Chapter 6.0. Chapter 7.0 covers issues relating to laboratory-based analyses, while Chapter 8.0 deals with field-based analyses. These two chapters are not intended to provide complete, definitive answers to all the questions the designer of a wet weather analysis program might ask, but the responses to common questions represent the range of information developed as a part of this research.

Conclusions

A number of conclusions have been reached as an outcome of this research; several are critically important when addressing wet weather discharge impact assessment.

First, it is essential to have a measure of hydrograph response in parallel with any toxicity assessment of stormwater, and it is essential to apply test systems that are appropriate to the time scale of exposure. This research also found that contaminant concentrations present during wet weather events follow predictable patterns of a first flush high concentration, followed by lower concentrations later in an event due to dilution from rainfall/runoff. Other peaks in contaminant concentration can be related to differential concentration peak times of travel from points in the watershed or are associated with sediment resuspension that occurs later in storm events.

Second, to assess the effects of the episodic contaminant levels associated with wet weather events on organisms or systems, it is necessary to move away from the organism-based approach used for continuous discharges to a time scale of response approach. Unfortunately, no single test system adequately meets all criteria required for wet weather event impact assessment, and standard WET tests, designed for continuous exposure conditions, are inappropriate for assessing some wet weather events. This research found that modifications to standard toxicity testing methodologies can produce new test systems that are more appropriate to wet weather event time-scale toxicity assessment. These account for post-exposure responses of organisms to short-duration exposures to contaminants.

Third, in the over 50 storms studied, discharges from a number of locations consistently showed moderate or high in-pipe toxicity; however, the in-pipe toxicity did not always impact the receiving water as measured by in situ tests or biosurveys. A critical finding was that changes in toxicity during an event can occur rapidly and sampling intervals as short as five minutes or less are needed to accurately measure event toxicity characteristics. Furthermore, at a single location, a sequence of storm events can produce varying levels of toxicity.

Fourth, this research found that regional testing indicated no fundamental differences in the characteristics of the toxic response to wet weather events that could be attributed to specific regional characteristics. The differences in toxicity appeared to be source- and site-specific, and generally tracked a response pattern that identified both first flush and later responses.

Finally, this research reaffirmed that the assessment, monitoring, and management of wet weather events needs must accommodate ecosystem/watershed issues in a time-scale toxicity framework.

Research Needs

What can be summarized from the extensive literature review, laboratory, and field studies conducted as a part of this research is that the special needs of wet weather discharge impact assessment are only now being defined in the context of time-scale toxicity, and research is needed in both fundamental and applied areas of toxicity testing and impact assessment. A number of fundamental and applied research needs have been identified as an outcome of this research, of which four are critically important when addressing wet weather discharge impact assessment.

First, research is needed to address test-system responses to variable exposure concentration and frequency of contaminants, monitoring fundamental organism processes and identifying specific mechanisms of effect. This lack of fundamental understanding of individual organism response translates to an even greater gap in our understanding of community/ecosystem response, where time-scale toxicity issues of wet weather events must be integrated with time scales of response of the communities and ecosystems. These longer time scales must consider both constant and episodic exposure. Second, research is needed on the contribution of storm flows to contaminated sediments, mechanisms of sediment contamination during storm events, and effects of the resuspension of contaminants associated with sediments during storm events. Third, because response to a toxicant is affected by environmental conditions, research is needed on the effects of physical stress on organisms and the impact of unstable habitat conditions on time-scale toxicity. Finally, research is needed to translate advances in the fundamental understanding of the physics, chemistry, or biology/ecology of the environment into useful tools to guide management and regulatory programs. Since there are few standard measures of time-scale toxicity, research is needed to provide the detailed, management practice specific, methods for impact analysis. Once a reasonable basis is provided for impact analysis, research is needed to validate management practice impact and, most importantly, develop predictive tools/models that will assist in the design of better management practices.

CHAPTER 1.0

INTRODUCTION

1.1 Introduction to the Project

This report is the final report for the project "Region Specific Time-Scale Toxicity in Aquatic Ecosystems." The project was initiated in September, 1993, with a review of biological test systems available for the measurement of time-scale toxicity and progressed to field and laboratory studies to assess time-scale toxicity. In both field and laboratory campaigns, the research has been directed toward the collection of data on biological test system responses to stormwater-related changes in water quality and the evaluation of test systems using criteria developed as part of initial project research. Test systems were identified from procedures developed in a test system selection process that has been the subject of constant review and evaluation throughout the project.

The project team identified four overall research objectives:

- **Objective #1**—Develop a database for frequency and duration of exposure for contaminants in combined sewer overflow (CSO) and stormwater runoff;

- **Objective #2**—Conduct a comprehensive review of the literature to identify biological test systems appropriate for use in detecting acute and chronic effects of CSO and stormwater discharges;

- **Objective #3**—Conduct a series of field studies to quantify the relationships between chemical toxicity and the frequency and duration of exposure of aquatic organisms to contaminants during wet weather discharges; and

♦ **Objective #4**—Develop an ecosystem-based management context for wet weather discharges that integrates the need for both regulatory criteria and the protection of ecosystem health.

Research conducted has progressed through several stages. Initially, Objectives #1 and #2 activities were emphasized, resulting in publication of an interim report—*Selecting Biological Test Systems to Assess Time-Scale Toxicity*—and completion of initial literature reviews. These reviews supported initial Objective #3 research to quantify relationships between chemical toxicity and the frequency and duration of exposure–time-scale toxicity.

The 1994 campaign involved sampling at several locations in a watershed receiving stormwater runoff and the use of a range of methods including common biosurveys, in situ use of caged organisms, and time-based storm event sampling. Samples were subjected to both chemical analyses and a toxicity test battery. The results from this initial campaign clarified issues relating to time-scale toxicity, such as sampling location and frequency and test-method selection. The data indicated that biosurveys produced little information on short-term time-scale toxicity. Further, toxicity test battery results suggested the need for specific examination of time-of-exposure issues in the laboratory. Therefore, in 1994, an extensive laboratory-based testing program was initiated to examine time-of-exposure to common whole effluent toxicity (WET) species (*Hyalella azteca* and *Ceriodaphnia dubia*), and the project team began planning to deploy successful test systems in different regions.

The 1995 field and laboratory campaign can be characterized as an effort focused by the results of initial research, which was further sharpened by experiences gained from regional field and laboratory studies. Field studies were conducted in Fort Worth, Texas, as well as Champaign, Illinois, and were supplemented with storm event samples collected as a part of the Mill Creek Watershed Project in Cleveland, Ohio. Laboratory studies were conducted at the University of North Texas (UNT) and the Environmental Research Laboratory, Duluth, Minnesota (ERL-D). The 1995 laboratory studies continued time-of-exposure experiments and expanded the laboratory analysis program to include fathead minnow (*Pimephales promelas)* and to evaluate stock and dilution water effects on results through testing at the UNT and ERL-D. In addition, analysis of further test systems was completed. Additional development work was carried out with the Microtox and *Ceriodaphnia dubia* IQ (enzyme inhibition) tests to increase their utility for monitoring wet weather events. A successful four-month deployment was made of the Mussel Monitor, monitoring multiple storm events from August through November, 1995. This field and laboratory research resulted in the production of an interim document, *Protocol for Wet Weather*

Testing and Assessment. The protocol integrated existing standardized impact assessment and analysis procedures with time-scale-specific analysis to support the assessment of both short-term and long-term changes in receiving system condition or quality.

The 1996 campaign was designed to address specific issues identified in the previous research. Specifically, an intensive sampling program was initiated at a storm sewer (Kaufman Lake Storm Sewer) near Champaign, Illinois, to provide a detailed water quality and toxicity record for a multiple storm sequence, relating storm event toxicity to in-stream impact monitored by sampling benthic macroinvertebrates and both in situ and sediment related toxicity. In addition, laboratory-based studies included toxicity identification evaluation (TIE), and completion of time-scale toxicity research. Other aspects of the research have featured a cooperative study with the Northeast Ohio Regional Sewer District (Mill Creek in Cleveland, OH) assessing storm event toxicity and continuing cooperation with the City of Fort Worth (further studies of the Cra site).

This sequence of laboratory and field- related research reflects the increased understanding of storm event toxicity. Initial studies evaluated a range of test systems and their responses to storm event conditions. The extent of the toxicity of storm water discharges and receiving water impact was found to be site-specific. Field investigations in Fort Worth, Texas, demonstrated the importance of sampling for toxicity screening near sources of stormwater. Consequently, the focus of the research shifted so as to determine the presence and timing of toxicity during storm events, and the decrease in toxicity with distance from the source, using both laboratory and in situ methods. With this progressive understanding of storm events, the interval between sequential stormwater samples taken for laboratory testing was decreased to as little as 150 seconds. This intra-event analysis supported the development of methods to better characterize toxicity during storm events and provided insight into methods of sampling suitable for storm event analysis.

1.2 Analysis of Existing Approaches and Issues

Issues surrounding the effect of wet weather related discharges on the environment have grown in importance as the regulatory focus of the Clean Water Act has shifted from effluents with continuous flow to episodic discharges produced by storm events. This change in focus and the changing regulatory scene necessitated a shift in approach when developing procedures for wet weather discharge impact assessment. The new approach demands careful integration of sampling and analysis procedures, coordinated with what is termed "time-scale" toxicity assessment and receiving system effects assessment.

Toxicity can be defined as the inherent potential or capacity of a test substance to cause adverse effects on living organisms. These effects can be either:

- Sublethal—that is, detrimental to responses such as enzyme function, bioluminescence, growth and reproduction, but not resulting in death within the exposure period; or

- Lethal—that is, causing the death of organisms by direct action. Death is usually defined as the cessation of all visible signs of movement or activity.

Considerable evidence indicates that elevated levels of contaminants in wet weather-related discharges can elicit a response in test systems. However, the measurement of a response to storm water discharges does not in itself constitute toxicity or mean that the discharge will cause an impact on the receiving water biota. A comprehensive and robust assessment of the effects of wet weather discharges can only be achieved by an understanding of the nature of test system responses and the effective use of an integrated assessment approach involving direct toxicity assessment as well as in-stream biosurveys and chemical analysis.

Although methods for sampling and impact analysis of continuous flow effluents are well developed and, for the most part, standardized (US EPA 1993a; 1994), no standard methods exist to determine the effects of storm-related episodic exposure conditions common to wet weather discharge events. Further, the assumptions supporting effect assessment for continuous flow effluents, such as standard WET testing, are inappropriate for some wet weather event analyses. The direct toxicity assessment requirements for episodic wet weather events differ markedly from those for continuous flow discharges since the assumptions for the latter are inappropriate for some wet weather event analysis. The intermittent nature of wet weather discharges means that the time scales of exposure are key in analyzing the responses of test systems, and the relevant time scales of exposure need to be reflected in any toxicity assessment program.

1.3 Report Organization

This report is organized into ten chapters. This introduction constitutes Chapter 1.0, and Chapter 2.0 deals with time-scale issues and develops a time-scale framework to support a comprehensive time-scale toxicity analysis by identifying the conditions that lead to organism exposure to contaminants in receiving systems (Objective #1). Chapter 3.0 provides a protocol for time-scale toxicity assessment, which considers issues of time scale and location in the identification of procedures for time-scale analysis. Chapter 4.0 is a review of biological test systems useful for time-scale toxicity analysis. This chapter builds on the review of the literature completed to meet Objective #2 and published in 1994 as *Selecting Biological Test Systems to Assess Time-Scale Toxicity*. Chapter 5.0 provides a review of methods developed and applied in this research. Chapter 6.0 provides information on the study sites and a summary of storm events monitored. Chapters 7.0 and 8.0 have been prepared to provide access to the extensive research record developed as a part of this project. Questions associated with time-scale toxicity, and laboratory and field assessments have been addressed by relating elements of the research record to support question responses. Chapters 7.0 and 8.0 are provided in a question and answer format and should be considered a supplement to the protocol reviewed in Chapter 3.0 in that these chapters will assist in dealing with specific implementation issues in time-scale toxicity analysis. Chapters 9.0 and 10.0 provide a summary of research findings and identify critical research needs in the further development of time-scale toxicity analysis. Appendices provide detailed information supporting regional storm event characterization, details on method development and application, and an ecosystem-based management paradigm.

CHAPTER 2.0

TIME-SCALE ISSUES

2.1 Introduction

The focus of this research project was time-scale toxicity, that is, toxicity in aquatic systems resulting from wet weather events. Many factors—physical, biological, chemical, and hydrological—influence, or are influenced by the time scales of wet weather events. For example, regional differences in hydrological patterns can influence event characteristics, including toxicity, while natural patterns of variation in biological communities cause their degree of sensitivity to vary. Clearly, understanding these relationships can help target a wet weather event assessment program and aid in the interpretation of the results obtained in order to arrive at appropriate management decisions.

In this chapter are discussed some of the more important relationships and influences on wet weather event toxicity, and the concept of a time-scale framework for wet weather event assessment is introduced. This framework forms the foundation for the wet weather event assessment protocol and the biological test system selection methodology that are developed in Chapters 3.0 and 4.0.

2.2 Time-Scale Issues in the Physical/Chemical Analysis of the Environment

Time scales required for wet weather event assessment can be short or long. For example, to analyze toxicity associated with a transient change in the concentration of a contaminant requires a short time scale, measured in seconds to hours. In contrast, where it is necessary to account for accumulation of sediment or contaminants or to assess habitat alteration in the receiving waters, a long time scale, measured in days to years, is required. Short time-scale analysis can be storm- and location-specific. Long time-scale analysis includes effects of multiple storm events or multiple locations over larger spatial scales.

Time-scale considerations are critical to both the design of an analysis/assessment program and the eventual interpretation of data from that program. Selecting which parameters to measure often depends on storm event characteristics. An intense thunderstorm often deposits a large amount of rain in a short time, while another, longer storm can consist of gentle rain falling for hours or days. To ensure precision and accuracy of contaminant concentration or flow variability measurements, the time scale must match the wet weather event. High frequency sampling might be required for short events, while long events might require careful collection of composite samples from the entire storm.

In addition, other factors can determine time scales. Since a detention basin is designed to hold a given volume of water, which then drains slowly to the receiving waters, the detention time becomes relevant when natural flows are modified. Because treatment technologies are designed to meet specific needs, the time scale for a performance analysis might be treatment-technology-specific, as well as site-specific.

The time scale appropriate to receiving system impact assessment will be site-specific, as well as specific to the indigenous aquatic life. For example, a headwaters stream will have a short hydraulic concentration time for any rainfall event so that it is important to sample headwaters with a short interval between samples. Other factors determine the time scale of assessment at specific sites. An area of sediment deposition in a stream requires a time scale of assessment that spans the period of deposition, which might be further modified by decomposition rates. When aquatic life is considered, a major time consideration is life span. Organisms might be short or long-lived, each species requiring a different time scale for testing or analysis. Finally, time must be considered in terms of the duration of exposure, which, along with the concentrations of contaminants, determines toxicity.

Establishing a time scale for wet weather discharge assessments requires a careful analysis of location, storm characteristics, sampling needs, and receiving system and program objectives.

- **Location issues** include position in the watershed, as well as the constraints a specific site places on hydrology, expected water quality, and ecology;

- **Storm issues** include seasonality, frequency, return period, and intensity class—all factors that alter water quality expectations and affect short and long-term concentration-duration relationships, which define toxicity and eventual receiving system impact;

- **Sampling issues** define the precision required in contaminant identification and the associated identification of concentration variability, characterize the dynamics of contaminants in treatment technologies (and eventually pipes and open channel flow), assist in the determination of contaminant fate, and establish time-scale bounds for biological effect analysis;

- **Receiving system issues** are associated with the physical, chemical, and biological/ecological characteristics of the receiving system, which combine to constrain the types of time-scale analysis that are needed, or even possible; and

- **Objective issues** set a time scale for analysis and are constrained by the time-scale characteristics of the receiving system/discharge combination, which is the subject of the analysis.

Spatial and temporal scales must be considered when analyzing wet weather-related water quality issues in watersheds. With large spatial and temporal scales, the emphasis is on source development and contaminant loading. With smaller spatial scales, the emphasis is on concentration and duration of exposure. Further, spatial and temporal scales are important factors that define cause and effect. As scales of analysis are reduced, a better definition of cause and effect is possible.

2.3 A Time-Scale Framework for Wet Weather Event Assessment—Hydrology

2.3.1 Introduction

Objective #1 of the research project supports a comprehensive time-scale toxicity analysis by identifying the conditions that lead to organism exposure to contaminants in receiving systems. The objective was to develop a database for frequency and duration of exposure for contaminants in combined sewer overflow and stormwater run-off, and this was approached in several ways. One approach investigated regional hydrologic characteristics that would help define storm events, and a library was assembled that provides information on storm event characteristics (Appendix A). This library provides a regional perspective on storm event characteristics and supports analysis of specific studies conducted in various regions. Analyses have been performed on the Kaskaskia River near Champaign, IL; Johnson Creek in the Willamette River Basin at Sycamore, Oregon, The Cuyahoga River at Independence, Ohio (representative of Cleveland, Ohio), Ware Creek near Toano, Virginia (representative of Virginia coastal areas), the Trinity River in Fort Worth, Texas, and the Salt River in Phoenix, Arizona. At each site, hydrologic data were used to characterize hydrographs of typical storm events (Appendix A) and to develop summaries of percent of total storms in small, medium, and large categories, and the mean time between storms (Table 2-1).

Table 2-1. Summary of Watershed Analysis

Watershed	Data Collection Period	Storm Events (% by Category)			Mean Time between Storm Events (Days)			
		Small	Medium	Large	Spring	Summer	Fall	Winter
Kaskaskia River, IL	1986-89	59.3	31.6	9.1	6.06	6.66	9.47	7.24
Johnson Creek, OR	1989-93	64	22.4	13.6	4.36	6.45	4.36	4.45
Cuyahoga River, OH	1989-93	72.2	18.2	9.6	4.21	4.46	4.37	4.62
Ware Creek, VA	1989-93	67.3	24.0	8.7	4.28	4.44	4.70	4.57
Trinity River, TX	1989-93	80.4	9.6	10.0	5.07	6.88	7.56	6.08
Salt River, AZ	1983-91	67.3	24.0	8.7	5.8	N/A	6.4	2.8

2.3.2 Summary

The hydrologic analyses performed as a part of this study yielded a library of information that serves as a regional foundation for the prediction of frequency and duration of exposure for contaminants in CSO discharges and stormwater run-off. The analysis identified regional differences in the times of storms, the time between storm events, storm size, and hydrograph characteristics for storm events. These factors all affect the contaminant exposure profile, and, therefore, the toxicity of an individual storm event. Discussion of the requirements for toxicity assessment of storm events can be found in Chapter 7.0. Hydrologic analysis also provided detailed information for local field sites (such as the Copper Slough, Mill Creek in Cleveland, and Fort Worth study sites near the Trinity River), where expected storm and flow conditions assisted in the design of sampling programs.

2.4 A Time-Scale Framework for Wet Weather Event Assessment—Toxicity/Biology/Ecology

A number of time-scale issues affect the potential impact of wet weather events in receiving systems and on how toxicity tests can reflect wet weather event time scales. Of these issues, the most important is how long the organisms are explosed to a contaminant. This, together with the exposure concentration, defines the contaminant "dose." The concentration/duration of exposure relationship is the foundation for procedures for any toxicity analysis, and is particularly important when considering receiving system impact assessment procedures for wet weather event application.

A test system is defined as a measurement or analysis unit that integrates a complex response and is used to examine or assess the effect of toxicants (Herricks, Milne, and Johnson, 1994). Test systems can range from simple biochemical assays to experimental manipulation of ecological systems. In standard test methods, such as WET testing procedures, the time scale established in the procedure is based on the time required to produce a specific response (e.g., LC_{50} or EC_{50}) in the species selected for testing. This is an "organism-based" approach, which has supported the development of methods to measure acute or chronic toxicity, which in turn have been, and continue to be, widely used in toxicity testing and assessment programs (e.g., WET testing). The organism-based approach differs from a "time scale of response" approach, in which the time-scale characteristics of the response, independent of the organism producing that response, is the major criterion for selecting a toxicity testing procedure. The "time scale of response" approach is emphasized in wet weather analyses and associated test system selection procedures. Therefore, in a wet weather toxicity assessment program, an expected concentration/duration condition is used to select a test system that will adequately respond to exposure conditions, specifically the time scale of the exposure.

Although wet weather event time scales vary widely at the same location, as well as regionally, the project team identified three time scales for a starting point for a time-scale toxicity determination in wet weather assessments. If a measure is intended to assess an intra-event effect, the analyses must accommodate rapidly changing conditions. In the **intra-event time scale**, concentrations might vary by several orders of magnitude, and exposure times might be as short as seconds, certainly minutes and possibly a few hours. In practical terms, intra-event time intervals are measured in minutes for short duration events and hours for longer events.

[illegible]
assess the toxicity variation within a single storm event
characterize the range of toxic conditions in an effluent with changing flow
characterize the range of conditions occurring at a site during a storm event
identify toxic contaminants and their dynamics
identify concentration vs loading effects
identify sources of contamination and location
identify likely mechanisms of toxicity
predict receiving system effects based on site-specific toxicity

The second time scale is event, when measures of concentration variability are reduced by sampling approach (e.g., composite sampling) and the duration of exposure can be hours to days. The actual determination of an event time scale is both storm- and site- specific. In general, an event time scale spans the time from the initiation of runoff to the termination of the receding limb (Bras, 1990). This time span can be determined both hydrologically (Linsley, Kohler, and Paulus, 1975) and by observation of water quality changes (e.g., return to pre-storm specific conductance values). In the Copper Slough watershed at downstream locations, the average event duration determined hydro logically was 1.36 days with a standard deviation of 1.5 days (a maximum of 8.88 and a minimum of 0.29) and from 1.5 to 4 days based on water quality change. The event time scale is also modified by treatment technologies, particularly detention facilities. When stormwater is detained and released slowly after rainfall has ceased, the actual event duration can be extended well beyond normal storm hydrograph expectations. An event time-scale analysis finds application when within-event change is "averaged" using composite samples, or storm-related change is modified by detention and mixing management practices.

For convenience, event time scales fall into two categories: Category #1 would be appropriate for short-duration, convective storms in which event duration is measured in hours, and Category #2 where event duration requires multiple composite samples, or best management practices (BMPs) extend a storm's influence so that an event duration is measured in days (24-hour increments).

[illegible]
analyze whole storm effects
measure the effects of event mean concentrations of contaminants
assess the effects of total contaminant loading during a storm
analyze event-related toxicity as modified by management practices (e.g. detention)
assess BMP performance against water quality criteria
identify sources of contamination and location
relate intra-event or short duration storm events results to common WET testing that uses fixed exposure times of 48 to 96 hours
assess short-term response of specific receiving system components to a whole storm; confirm receiving system effects predicted from other testing

Finally, a **long-term** time scale is typical of multiple storm events or storm-related residuals that produce a chronic exposure condition. The long-term time scale is particularly applicable when separating wet weather events from other watershed influences.

[illegible]
assess the effects of multiple storm events
assess the chronic effect of single or multiple storms
compare seasonal change in storm event effect
compare effect among multiple sites
assess community or ecosystem effects of storm water discharge(s)
determine receiving system state and condition with the intention of monitoring confirmed wet weather event effects

An indicator for a long-term time scale must meet different criteria from those appropriate to shorter time-scale indicators. Further, it should be recognized that longer time scales introduce greater complexity in the determination of cause and effect, requiring either a greater number of indicators for confirmation of effect or indicators that require a longer time span for completion of analysis where multiple events and other interacting factors affect results. Wet weather toxicity testing and assessment must reflect the varying, extended residence time in the receiving system for both non-conservative and conservative contaminants in wet weather discharges. Finally, a wet weather toxicity testing and assessment program also includes a receiving system "residuals" component that considers the extended duration of potential exposure associated with accumulated contaminants directly attributed to wet weather discharges.

These three time-scale divisions recognize that effect identification, test system selection, actual measurement of an effect (physical, chemical, biological/ecological, etc.), and analysis and interpretation of consequence must all meet criteria that are specific to an identified time scale.

Table 2-2 is a summary of the types of measurements appropriate to different time scales. For a wet weather-based test system selection, if toxicity is the indicator, then in short-term exposures (intra-event time scale) where concentration transients might be very large (e.g., orders of magnitude), rapid responses will be the best indicators. When analyzing whole events, for example as modified by BMPs, the time-scale analysis selected (event time scale) should reflect the fact that BMP effluents will have some characteristics of the storm event (e.g., episodic nature with variable volume and concentrations associated with the effluent), but BMP effluents will typically be less variable with longer, but not constant, effluent flow times. Finally, toxicity analysis related to extended contaminant residence or accumulation of contaminants will require tests appropriate for a long-term time scale, where exposure durations are very long.

2.5 A Time-Scale Framework for Wet Weather Event Assessment—Ecology

2.5.1 Seasonal Effects

The impact of wet weather events potentially reveals seasonal changes due to the biological variability of the system. Many aquatic species show seasonal patterns in presence or abundance. In particular, many insect species have aquatic larval stages but terrestrial adult stages. Some of these insects represent particularly pollution-sensitive groups, for example stoneflies and mayflies, so the impact of a wet weather event on the aquatic community might be more severe during the season when these aquatic forms are present.

Table 2-2. Example Measurements Used to Apply the Time-Scale Concept

MEASUREMENT CHARACTERISTICS	TIME SCALE		
	INTRA-EVENT	EVENT	LONG-TERM
PHYSICAL	Discharge vs. time	BMP modified discharge	Discharge/channel morphology characteristics
CHEMICAL	Hydrograph sequenced contaminant concentration	Flow-weighted average or composite sample concentration	Sediment accumulation
BIOLOGICAL/ ECOLOGICAL	Physiological and/or behavioral response, modified whole effluent analysis procedures, time-scale toxicity measures	Effect testing using whole effluent approaches ; may include acute or sub-chronic testing	Sediment toxicity and/or field bioassessments
INTEGRATIVE	Simulation/modeling, bacteria and toxicity assessment	Standard exceedance frequency, habitat	Watershed comparisons
AESTHETIC	Debris sampling/ quantification	Public attitude surveys	Public involvement groups

Intimately related to seasonal variability is the effect of organism life history. Most, if not all, organisms show varying degrees of sensitivity to contaminants at different stages of their life cycles. Usually, the

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young and developing stages are most sensitive. Consequently, the greatest impacts of wet weather events on community structure and long-term population viability occur when the most sensitive life stages are present.

2.5.2 Habitat

Habitat changes are associated with wet weather events at different time scales, from short-term sediment deposition and local scouring to major channel shifts. Sediments associated with wet weather events sometimes contain contaminants that have direct toxic effects on sediment biota either through immediate toxic action or through bioaccumulation. The hydraulic characteristics of storm events can also resuspend sediments, potentially exposing water-column biota to contaminants.

In addition to toxic effects, heavy sediment deposition alters the physical habitat, thereby affecting the receiving system ecology. Sediment removal and scouring from the hydraulic influence of wet weather events are other mechanisms of physical habitat alteration.

2.6 A Time-Scale Framework for Wet Weather Event Assessment—Watershed and Drainage System Location

The location issues important in establishing a time scale for wet weather discharge assessments consider the fundamental physical, chemical, and biological/ecological processes that operate in the watershed. These processes operate over different spatial and temporal scales and can be specific to a location in the watershed. For example, in a low-order stream reach, the changes in physical and chemical conditions produced by a wet weather event, as measured from baseline/baseflow conditions, will be of short duration. Although event duration is short, the magnitude of change is often great. Further, one can expect limited residual effects in a low-order stream because of high transport rates out of the system. To analyze or interpret wet weather event effects in a low-order stream, the focus is on contaminant concentration, rather than loading, while interpretation is simplified because the limited watershed area restricts possible sources. Furthermore, the potential for contamination is usually limited by the small watershed area associated with these small streams. In contrast, the changes in physical and chemical conditions produced by a wet weather event in high-order streams have longer durations. Although the change in physical and chemical conditions might still be rapid, the magnitude of this change is moderated by the increased baseflow and dilution capacity of these larger streams. In high-order streams, event duration is often long, reflecting the extended concentration time for flows from tributaries. In addition, the effect of contaminants can be extended, because residuals are stored or only slowly transported within these larger rivers. To analyze or interpret wet weather event effects in these larger rivers that have larger watersheds, the focus typically shifts to contaminant loading, and interpretation is complicated by the potential effects of multiple sources. Furthermore, larger watershed areas also introduce the complications produced by a more diverse land use that can be expected to alter both baseline/baseflow conditions and wet weather conditions.

It is possible to extend this analysis of location to considerations of toxic potential. The disturbance of any watershed, natural or anthropogenic, is expected to alter run-off volume and chemical characteristics of the run-off (Borman et al., 1968; Vitousek et al., 1979; Webster and Patten, 1979; McDowell and Likens, 1988; Close and Davies-Colley, 1990; Edwards and Helvey, 1991). The result is that water quality alterations are magnified by the combined effects of disturbance and the concentration of contaminants. The effects on receiving system aquatic life are short-term if the natural assimilative capacity of the stream/watershed system is not exceeded and long-term if deposited contaminants lead to residual effects. As noted above, watershed location (stream order) is critical in determining the relative importance of concentration or loading. When low-order streams are compared with high-order streams, the effects of changes in run-off volume and contaminant concentration are less likely to be moderated by ambient flows and lead to acute toxicity and profound, short-term change in receiving system biota. In high-order streams, contaminant concentrations might not be acutely toxic, but the residual effects produced by deposition, storage, or slow transport lead to chronic toxicity and the effects on receiving system biota are subtle. As the ratio of disturbed to undisturbed land increases, the risk of severe impact also increases. Recent analyses indicate that any increase in impervious area above 15% to 20% will severely limit ecological integrity (Shaver et al., 1995).

This complex set of relationships among spatial scale, duration of effect, location, and risk of impairment requires that wet weather discharge assessments use techniques appropriate to both time scale and watershed location. It is possible to use watershed location, and location-specific time scale and exposure characteristics as the starting point for selection of assessment procedures.

CHAPTER 3.0

PROTOCOL FOR TIME-SCALE TOXICITY ASSESSMENT

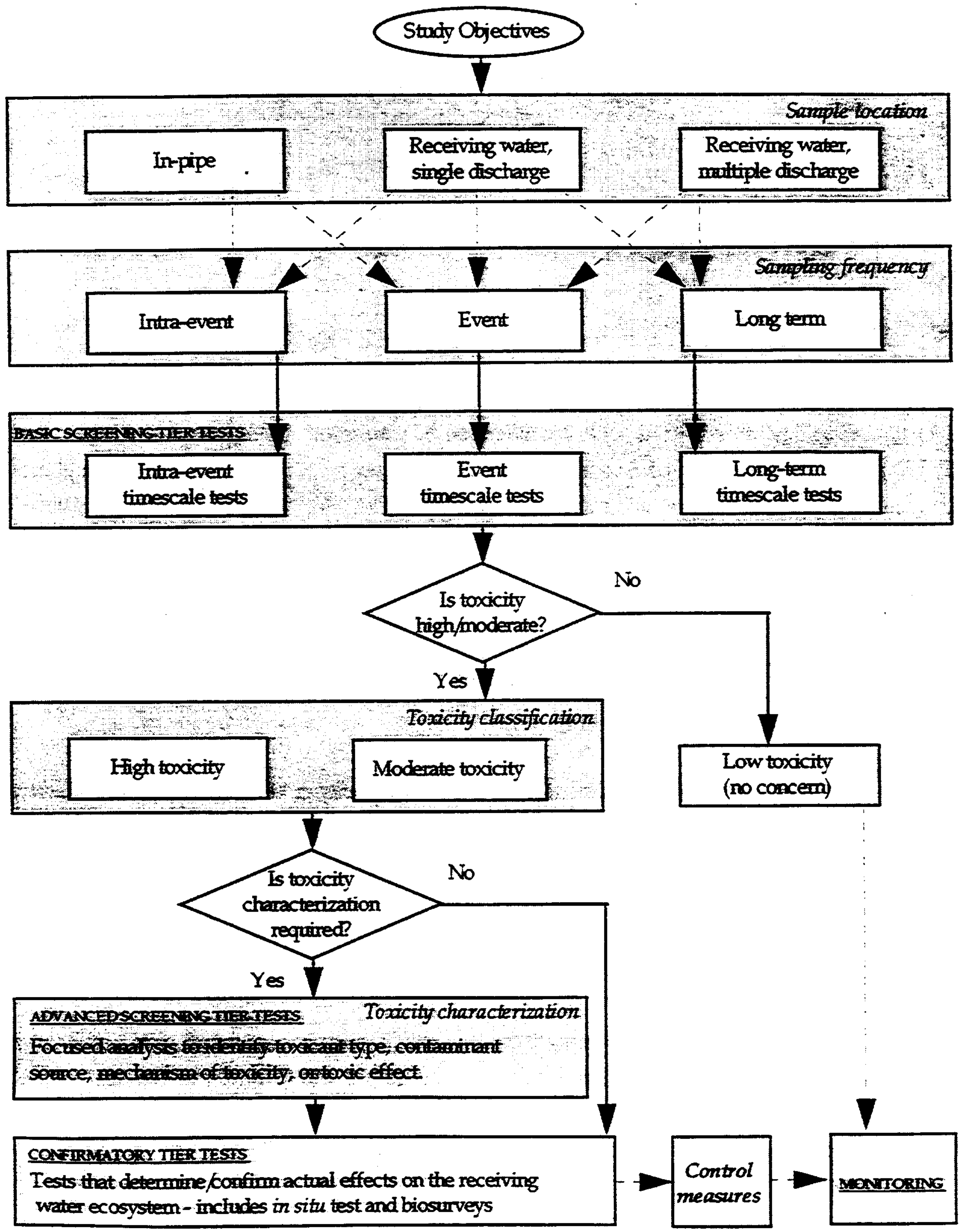
3.1 Introduction

The protocol for the assessment of wet weather discharge effects on receiving systems starts with a design specification and ends with consideration of watershed issues, which are important in defining sampling location and frequency. The development of this design specification is based on general program objectives and refined by study plans that address specific questions related to the objectives. Primary design elements take into account sampling location and sample-collection frequency. Samples collected are then be subjected to an appropriate time-scale toxicity analysis that follows a tier testing approach. Tier testing is initiated with a comprehensive set of screening procedures that may involve both basic and advanced screening tests. A schematic illustration of the protocol is given in Figure 3-1, and Chapters 7.0 and 8.0 of this report provide more detailed information about applying the protocol.

Basic screening tests establish the presence or absence of toxicity in wet weather event discharges and allow a classification by degree of toxicity. Advanced screening tests can then be used to identify sources, characterize event toxicity to assist in defining what we will term an event toxic unit, and define effect characteristics to guide both short- and long-term assessments of receiving water impact. Based on the results of basic and advanced screening tests, analysis might continue to a confirmatory tier that determines or confirms actual effects in the receiving water ecosystems.

Further analysis might focus on a long-term monitoring program to detect any low-level or cumulative effects on the receiving water ecosystem. Monitoring can confirm that there are no such effects after an initial identification of low stormwater toxicity or after implementing control measures to reduce stormwater toxicity, such as a detention facility. Time-scale toxicity testing can be combined with chemical analyses, habitat analysis, and other assessment program elements, and the results used in an integrated assessment that will meet a range of study objectives.

Figure 3-1. Schematic Overview of Time-Scale Toxicity Test Application Protocol



3.2 Sampling Location

The first stage of assessing wet weather discharge effects is the selection of sampling location(s). Applying a time-scale context when locating sampling sites recognizes that different locations might be subject to both different concentration profiles in a storm event and different event durations. The differences in location also reflect the influence of hydrologic change on channels and stability and the level of chemical complexity that occurs in samples. Samples from sewer networks might contain run-off from one or a few significant sources. Samples from receiving systems might reflect a few sources in headwaters locations or multiple significant sources in downstream locations. Furthermore, the sampling location within a watershed helps determine which biological or ecological tests are needed to address differences in flora and fauna along ecosystem gradients.

When selecting sampling locations for a wet weather discharge assessment, it should be recognized that while location might dictate aspects of sampling frequency and biological or ecological test system validity, sampling and testing results determine sampling locations. The appropriate sampling location depends on the objective of the study and wet weather event characteristics. Three objective-related sampling location categories are proposed: (1) in-pipe; (2) receiving system-single discharge; (3) receiving system- multiple discharges and outlined in Table 3-1.

Although the time-scale approach defines the general location of sites, other aspects need to be considered. These include safety of access and, where in situ tests are used, selection of sites with similar depth, flow, and substratum characteristics.

For receiving system sampling, an appropriate reference site must be selected. Depending on the system and the study objectives, this may be either an upstream, non-impacted site or a site on another, non-impacted watercourse.

3.3 Sampling Frequency

The second stage of time-scale analysis is the selection of sampling frequency. Applying a time-scale context in a wet weather discharge assessment program requires that sampling frequency be set to meet multiple requirements. These requirements could include: identification of the effect on receiving systems from wet weather events; providing support for test system selection; allowance for the actual measurement of event effect; and support for the analysis and interpretation of event consequence.

Table 3-1. Defining Sampling Location	
In-Pipe	If the objective of a stormwater study is analysis of a defined drainage area or assessment of performance of control facilities, an in-pipe sampling location may be specified to enable toxicity testing of stormwater at the point of discharge. Where it is not possible to sample in-pipe, a near-discharge location will ensure minimum mixing with receiving waters. The dilution and dispersion available in the receiving water for toxic in-pipe samples must be considered before any conclusions can be drawn on the potential environmental impact. In-pipe sampling at points in a sewer system is particularly valuable in source identification.
Receiving System - Single Discharge	If the objective of a study is the assessment of a single discharge, sites can be selected to provide a reference sample and a well-mixed discharge/receiving system sample that identifies the effect of the discharge as modified by receiving waters (particularly applicable when in situ biological testing is used). In single discharge location selection, sampling location is based on both discharge and receiving water characteristics at the discharge site. Single discharge locations are useful in initial source identification, in defining event-related discharge variability with receiving water variability, and as an initial stage of receiving water impact assessment.
Receiving System - Multiple Discharges	If the objective of a study is: 1) establishing reference conditions for a location in a watershed; 2) the assessment of multiple, or diffuse-source discharge effects at a site or sites; or 3) long-term surveillance of dynamic (wet weather)/static (baseflow) receiving system condition, then location of sampling points will be based on both discharge locations and receiving water characteristics. Multiple discharge sampling locations requires a commitment not only to large spatial scales, but also to extended temporal scales, including multiple year studies.

The appropriate sampling frequency depends on the objective of the study and wet weather event characteristics. In general, with more frequent sample collection it is possible to improve understanding of parameter variability and assist in ascertaining concentration/duration values for contaminants to support development of exposure bounds for biological test system selection and use.

Three sampling-frequency categories are proposed for the initial development and implementation of a wet weather discharge assessment program: (1) intra-event; (2) event; and (3) long-term. Each category provides information appropriate to the types of objectives addressed by the relevant time scale. Details of these are found in the Table 3-2.

Table 3-2. Defining Sampling Frequency	
Intra-event	Time-based or flow-based sampling to characterize variability within a single storm event. Multiple, discrete samples are collected to track toxicity through the event's duration. *Sample collection procedures include collection of multiple samples during the event using either fixed time interval sampling or flow proportional sampling. Primary dependence is on discrete, grab samples, but event length can dictate that consecutive time-specified composite samples be collected during an event. Continuous logging of water quality change facilitates identification of intra-event variability and supports time or water quality change-based sample intervals.*
Event	Event sampling is designed to characterize average conditions or average change produced by an event. Samples will be time-based or flow-based composites, giving an integrative sample representing the whole event. *Sample collection procedures include single or multiple composite samples collected to represent average conditions over a given time period, typically approximating storm duration. For short duration, Category #1, events, typical of convective storms, a single composite may be used. For longer duration, Category #2 events, multiple composite samples may be collected over several days. Event sampling for a BMP may also use single or multiple composite samples collected over a time appropriate to the design "fill/drain" cycle produced by a single event. Continuous monitoring of water quality change provides a basis for actual identification of event duration and time or water quality change-based sampling for accurate event composite samples.*
Multiple-Event	Long-term sampling requires consideration of multiple events. Sample collection procedures should provide sufficient information to address natural system variability, identify single event effects with certainty, and support separation of event effects from other influences on receiving system quality. *Sample collection procedures depend on study objectives and system complexity. Discrete sampling may be used but dependence is primarily on periodic composite sampling and the use of in situ monitoring techniques (which do not require sample collection). Continuous monitoring of water quality change provides a basis for development of comparisons between storm events and providing a long-term record for evaluating intra-event, and event sampling efforts.*

3.4 Biological Tier Testing

3.4.1 Test Tiers

Biological/ecological testing operates at different tiers of complexity ranging from simple screening tests to more complex definitive and confirmatory procedures. Biological testing involves both laboratory toxicity analysis and field-based organism, population, and/or community/ecosystem analyses. The project team proposed a two-tiered assessment strategy for wet weather event discharges (Table 3-3).

Table 3-3. Defining Biological Testing Tiers

Screening	Using simple, cost-effective tests to make preliminary decisions about hazard or risk	
	Basic:	Initial tests or analyses intended to illuminate the problem and supply sufficient data to identify toxicity and classify samples to be of no, moderate, or high toxicity.
	Advanced:	Advanced screening tests lead to a more focused analysis and might be selected to identify sources of contamination, better characterize individual storm events for later comparison or classification, or identify toxic effect that can be used to direct confirmatory testing toward appropriate targets.
Confirmatory	Analysis based on long-term testing procedures that involve field-based environmental/ecological analyses (such as in situ tests and biosurveys) to confirm effects predicted by earlier test tiers. Confirmatory testing integrates with monitoring efforts that are designed to identify unanticipated long-term or low-level effects.	

In this tier testing scheme, the basic screening tier uses accepted screening or range-finding procedures, modified to provide a measure of undiluted sample effects and to consider time scale of exposure issues. The advanced tier screening tests and initial confirmatory analyses take the place of the predictive tier commonly used in hazard evaluation schemes. Therefore, screening tests might be followed by confirmatory tier analyses based on study objectives or lead directly to establishing long-term monitoring programs.

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3.4.2 Test Time Scales

In the time-scale approach to wet weather event assessment, the time of exposure for the selected test system is based upon study objectives and site-specific characteristics. For each testing tier, tests must meet multiple criteria, including the appropriate time-scale requirements (Table 3-4); the appropriate exposure duration (time scale) is defined by the interval between discrete samples or the characteristics of the composite samples.

Once the appropriate biological testing tier(s) and testing time scale(s) have been identified, the most appropriate test systems must be selected. As the range of possible test systems increases, the task of selecting the most appropriate test for a given purpose becomes more difficult. Moreover, it is unlikely that a single test will fully meet all the criteria required for a particular tier application. Chapter 4.0 presents a simple and objective methodology for test selection that builds on an earlier project report (Herricks, Milne, and Johnson, 1994). Test selection is based on how test systems meet the required time-scale criteria. In all cases, a battery of tests (that is, two or more) should be used for basic and advanced screening for the different time scales.

3.4.3 Classification of Toxicity

The classification of time-scale toxicity is developed for intra-event and event time scales using basic screening test data; both sample specific toxic response and the number of samples exhibiting toxic response during an storm event/sample collection campaign must be considered. For either discrete or composite samples that are collected during a storm, the concentrations of pollutants present varyies through the hydrograph, possibly by several orders of magnitude. The highest concentrations of most pollutants are associated with the first flush. As rainfall continues, the concentrations of toxicants decline with dilution, although actual concentrations depend on source location, loading, and concentration time (time of travel). If concentrations of toxicants are sufficient to elicit a response in test systems, it can be used to classify the toxicity of an event. Basic screening test systems with pre-storm samples and samples from reference sites have shown that a variable, but low, level of toxic response (less than 20% effect) is common for the test systems used. Based on the expected "background" effect, a toxicity classification has been developed:

- **No toxicity**: Responses measured in undiluted samples do not exceed 20%
- **Moderate toxicity**: Responses measured in undiluted samples are between 20 and 70%
- **High toxicity**: Responses measured in undiluted samples are greater than 70%.

Table 3-4. Defining Biological Testing Time Scale

Time scale	Biological testing tier		
	Basic	Advanced	Confirmatory
Intra-event	Laboratory tests with exposure durations of minutes to a few hours measuring responses in undiluted samples.	Laboratory tests with exposure durations of minutes to a few hours measuring responses in a concentration series to derive $EC(LC)_{50}$ value, which may simply establish toxicity or be used to identify causes or sources of toxicity.	Laboratory tests with exposure durations of minutes to a few hours measuring responses in undiluted samples or concentration series. Tests may simply establish toxicity or used to confirm the causes or sources of toxicity.
Event	Laboratory tests with exposure duration appropriate to the event timescale are used. Test durations of 24 h or less are appropriate for Category #1 events. Because test durations of greater than 24 hours are appropriate for Category #2 it is often convenient to develop exposure regimes in increments of 24 h. Response is measured in undiluted samples.	Laboratory tests with exposure duration appropriate to the event timescale are used. Test duration of of 24 h or less are appropriate for Category #1 events. Because test durations of greater than 24 hours are appropriate for Category #2, it is often convenient to develop exposure regimes in increments of 24 h. Response is measured in a concentration series to derive $EC(LC)_{50}$ value. Tests may simply establish toxicity or be used to identify causes or sources of toxicity.	Laboratory tests with exposure duration appropriate to the event timescale are used. Confirmatory testing often employs exposures of 24-96 h to provide correlative measures to common WET protocols, particularly when testing is used to establish toxicity or to confirm the causes or sources of toxicity. Chronic laboratory tests to investigate the impact of loading on toxicity or in situ deployments to verify impact in the receiving water may also be used.
Long-Term	Laboratory tests used in intra-event or event analysis of undiluted samples. Single events are integrated to provide a picture of multiple event toxicity.	In situ deployments to verify impact in the receiving water.	Biosurveys

For samples taken in receiving systems or end-of-pipe locations where pipe flows might be diluted by the receiving system, sample toxicity is determined by comparing responses for the storm event samples with those measured during pre-storm conditions. A minimum of two pre-storm samples should be collected, although the number of pre-storm samples collected should reflect the variability in receiving system quality. The classification of the toxicity of an event reflects the subtraction of pre-storm values from the maximum toxic response observed during the storm where multiple samples are tested or the response of the composite where a single sample is tested. For in-pipe analysis where no dilution with receiving waters occurs, and a low or absent dry weather flow precludes pre-storm sampling, toxic response is used directly in the classification scheme.

The classification of toxicity is also based on the consistency in toxic response observed in different test systems exposed to the same sample. Different test systems are expected to show different sensitivities to pollutants and, given the complex nature of wet weather discharges, it is not surprising that different test systems exhibit different toxic responses. Therefore, toxic response can be further classified based on the number of test systems showing a toxic response. If only one test system responds above a no toxicity threshold, the toxicity is considered specific. The toxic response can be considered moderate or high (according to the level of response), giving rise to a specific/ moderate or specific/high classification. If two or more test systems show a toxic response, the toxicity is considered general. A moderate general toxicity occurs when there is a consistent indication of moderate toxicity in samples, particularly if there is a high degree of variability in the percent effect among test systems. A high general toxicity occurs in samples when multiple test systems have high toxicity.

Further classifications of samples taken during storm events (intra-event) are based on the frequency and position of toxic response observed during a storm event. If toxic response is observed in few samples (< 20%), with no pattern, the toxicity is considered infrequent. If toxicity is observed in 20% to 50% of samples, the toxicity is considered intermediate frequency. If toxicity is observed in the majority of samples (>50 %), the toxicity is considered consistent. Sample toxicity can be grouped, and response groups might be related to position in the hydrograph (e.g., first flush or hydrograph peak).

On this basis, a sample would be characterized as having no toxicity if a < 20 % response is indicated by all test systems in the battery of tests selected for analysis. A sample would be classified as specific moderate toxicity if a 20% to 70% response was measured for only one test system and a general moderate toxicity if a 20% to 70% response was observed for two or more test systems. A sample would be classified with either specific or general high toxicity dependent on the number of test systems with a response of greater than 70%. Sample toxic response would be used to characterize storm event toxicity, so that the observation of toxic response in only one or two samples at a wide interval would result in a storm event being classified as infrequent and specific/general, and moderate/high toxicity depending on the nature of the responses in the test systems. This system also allows classification of toxicity based on time of occurrence during the hydrograph, such as moderate, first flush. Table 3-5 summarizes the scheme proposed for classifying wet weather event toxicity. The nature of the classification depends on the sampling frequency adopted, and for event toxicity where a single composite sample is tested, the issues of number of samples showing toxicity and their position in the hydrograph are irrelevant.

For each location, there is usually a series of classifications that are event-specific. Since the concern is with the toxic potential of the discharge, the actual classification (and the need for further action, such as toxicity characterization) should be based on the worst case situation rather than an average of the series of values.

It is important to recognize that for in-pipe analysis, the available dilution and dispersion in the receiving water must be considered before any conclusions are reached on the potential environmental impact of storm events.

3.5 Protocol Integration in Watershed Analysis

3.5.1 Introduction

Application of the time-scale toxicity assessment protocol is governed by the physical, chemical, and biological processes in the watershed. These processes operate over different spatial and temporal scales and might be specific to a location in the watershed (Section 2.6). Watershed-focused management is needed to meet ecosystem integrity goals. With this recognition, the U. S. Environmental Protection Agency (US EPA) has developed a Watershed Protection Approach (WPA). The WPA helps to create water quality programs that:

- Feature watersheds or basins as the basic management units;
- Target priority watersheds for management action;
- Address all significant point and nonpoint sources; and
- Address all significant pollutants or stressors.

Table 3-5. Scheme Proposed for Classifying Wet Weather Event Toxicity

Toxicity Classification	Response in Tests (%)	Test Systems Responding	% of Samples Showing Toxicity and Position
Intra-Event			
No toxicity	<20	2 or more	-
Moderate/specific/infrequent/first flush	20 - 70	1	<20, first flush
Moderate/specific/infrequent/peak	"	"	<20, peak
Moderate/specific/intermed. freq./first flush	"	"	20-50, first flush
Moderate/specific/intermed. freq./peak	"	"	20-50, peak
Moderate/specific/frequent/first flush	"	"	>50, first flush
Moderate/specific/frequent/peak	"	"	>50, peak
Moderate/general/infrequent/first flush	"	2 or more	<20, first flush
Moderate/general/infrequent/peak	"	"	<20, peak
Moderate/general/intermed. freq./first flush	"	"	20-50, first flush
Moderate/general/intermed. freq./peak	"	"	20-50, peak
Moderate/general/frequent/first flush	"	"	>50, first flush
Moderate/general/frequent/peak	"	"	>50, peak
High/specific/infrequent/first flush	>70	1	<20, first flush
High/specific/infrequent/peak	"	"	<20, peak
High/specific/intermed. freq./first flush	"	"	20-50, first flush
High/specific/intermed. freq./peak	"	"	20-50, peak
High/specific/frequent/first flush	"	"	>50, first flush
High/specific/frequent/peak	"	"	>50, peak
High/general/infrequent/first flush	"	2 or more	<20, first flush
High/general/infrequent/peak	"	"	<20, peak
High/general/intermed. freq./first flush	"	"	20-50, first flush
High/general/intermed. freq./peak	"	"	20-50, peak
High/general/frequent/first flush	"	"	>50, first flush
High/general/frequent/peak	"	"	>50, peak
Event			
No toxicity	<20	2 or more	-
Moderate/specific	20- 70	1	-
Moderate/general	"	2 or more	-
High/specific	> 70	1	-
High/general	"	2 or more	-

- Set clear and achievable goals;
- Involve stakeholders during all stages of the program;
- Use the resources and expertise of multiple agencies;
- Are not limited by any single agency's responsibilities;
- Consider public health issues; and
- Consider all aspects of ecosystem health including habitat.

WPA projects also feature a strong monitoring and evaluation component, which is intended to provide data necessary for management decision making.

The Protocol for Time-Scale Toxicity Assessment should be considered an essential element of the strong monitoring and evaluation component of US EPA's WPA. A starting point for the incorporation of time-scale issues in watershed management is the Protocol's recognition of the importance of watershed location on sampling frequency and influence of land use related contaminants sources on the selection of tests in a test battery. The Protocol guides selection of sampling techniques and test systems that consider relationships among spatial scale, duration of effect, location, and sources of contaminants. The Protocol recognizes that measuring the effect/impact of wet weather discharges/flows on receiving system biota and associated measures of ecological integrity begins with an understanding of both contaminant concentration and duration of exposure.

3.5.2 Connecting to the WERF Watershed Management Strategy

The Water Environment Research Foundation (WERF) has recognized the importance of a watershed management framework as part of the search to identify alternative ways to use existing management and technical abilities to solve environmental problems. This watershed management framework provides a structure within which the time-scale toxicity test application protocol and wet weather flow/discharge management strategies can operate.

The WERF watershed management strategy is similar to the WPA. For example, Clements et al., 1996, identify nine elements for a watershed management framework: (1) geographic management units; (2) stakeholder involvement; (3) a basin management cycle; (4) strategic monitoring; (5) basin assessment; (6) a priority ranking and resource targeting system; (7) capability for developing management strategies; (8) management plan documentation; and (9) implementation. A critical element of this framework is identification and coordination of stakeholder roles in six core activities: strategic monitoring, basin assessment, assigning priorities and targeting, developing management strategies, management plan documentation, and implementation. The Protocol for Time-Scale Toxicity Assessment is designed to be an integral part of the WERF watershed management strategy. The Protocol assists in developing an accurate, high quality assessment of wet weather flow/discharge effects on receiving systems. Because time-scale effects differ from the effects of continuous flow, the time-scale toxicity test application protocol is a critical element of strategic monitoring and basin monitoring. Furthermore, time-scale toxicity analysis supports ranking, targeting, developing, and implementing management strategies. Therefore, the issues raised in Section 5.4.1 should be considered in the WERF watershed framework dealing with wet weather flows.

CHAPTER 4.0

BIOLOGICAL TEST SYSTEMS FOR TIME-SCALE TOXICITY ANALYSIS

4.1 Introduction

Reviewing available biological test systems and assessing their suitability for the assessment of wet weather event impacts was one of the early project activities. A detailed review was published in an interim report, *Selecting Biological Test Systems to Assess Time-Scale Toxicity* (Herricks, Milne, and Johnson, 1994). This chapter summarizes the findings on test system availability and suitability for wet weather event assessment and provides updated information on tests that have recently become available. It then presents a methodology for objectively selecting test systems for a particular application. Finally, an example is given for applying this system in the selection of a test battery.

4.2 Biological Test Systems with Potential for Wet Weather Event Assessment

Virtually any living system can be used in a bioassay (Schaeffer and Herricks, 1993). Unfortunately, not all living systems respond in the same manner to the same contaminant, nor can the response from a single organism necessarily be extrapolated to other members of the same species, other communities of organisms, or to the ecosystem (Herricks, 1993). For this reason, a major requirement for test system selection is the identification of the system or systems that both respond to a contaminant of interest and provide a basis for extrapolating effects to determine the risk of environmental damage.

The test systems available include any biochemical, physiological, or behavioral response that can be measured experimentally, or a range of structural and functional population, community, or ecosystem parameters that can be monitored for change. Test systems, as well as monitoring or assessment procedures, can operate at any level of the biological/ecological hierarchy and can be applied either simultaneously or sequentially in test batteries. To identify an appropriate test system, it is necessary to select procedures that measure a response that can be related to a contaminant or environmental condition of interest.

Test systems can be categorized according to the level of the biological/ecological hierarchy associated with the analysis or according to specific physical or chemical conditions of the receiving system. The biological/ecological hierarchy runs from the sub-cellular, enzyme level to the entire ecosystem (Figure 4-1). Test systems are available across most of the spectrum, from assays of biochemical function through assessments of whole communities. In practice, test systems generally stop short of the ecosystem level for practical reasons.

Figure 4-1. Biological and Ecological Organization Hierarchies

BIOLOGICAL HIERARCHY

Enzyme → Cell → Organ → Organ-System → Organism

ECOLOGICAL HIERARCHY

Organism → Species/Population → Community → Ecosystem

As a general rule, tests at the lower end of the biological/ecological hierarchy are more easily implemented under controlled conditions, but interpretation, in terms of an ecological context, is challenging. In contrast, tests at the top end of the hierarchy are more difficult to apply in a controlled manner, but the ecological relevance of the test endpoint is generally much clearer.

Table 4-1 lists the range of available test systems identified as potentially applicable for wet weather event assessment, categorized according to the biological/ecological hierarchy.

Table 4-1. Test Systems for Wet Weather Event Assessment

Biochemical Responses
- *Enzyme activity*
  - General metabolic enzyme activity
  - Mixed Function Oxidase (MFO)
  - Cholinesterase activity
- *Stress Proteins*
  - Heat shock proteins (HSP)
  - Specific stress proteins

Whole Organism Bioassays
- Lethality
- Bioaccumulation

Behaviorally-Based Sublethal Tests
- Preference avoidance
- Shell-valve closure in bivalves
- Locomotion in invertebrates

Physiologically Based Sublethal Tests
- *Basic physiological functions*
  - Heart rate
  - Respiration and ventilation rate
  - Muscular movement
  - Bioluminescence
- *Systems Integrating Physiological Function*
  - Feeding rate
  - Scope for growth
  - Growth
  - Whole body condition indices
  - Reproduction

Population and Community Responses
- Colonization
- Artificial streams
- Enclosures
- Biosurveys

4.3 Test Selection Criteria

To be deemed suitable for application in any context, biological tests must meet a number of different criteria, relating, for example, to response range, precision, cost, and ecological relevance. For application in the context of wet weather event assessment, additional criteria relating to time scales become important. The time-scale analysis concept, introduced in Chapter 2.0, is based upon the fact that wet weather event impacts have different time scales of effect and origin. This leads to the recognition of the three time scales (intra-event, event, and long-term) used as a starting point for applying wet weather assessment protocols.

Several key test-selection criteria, based on both wet weather event assessment and general test requirements, were developed and evolved over the course of the project. These categories indicate the broad issues that need to be considered when selecting tests for wet weather event assessment. Within each category, the individual criteria indicate the specific test requirements that must be considered. The test selection criteria are:

- *Previous application to wet weather events*

  This criterion relates to the number of studies in which the test has been successfully used for assessing wet weather events. Previous successful application will always be an important first consideration, not only because it indicates that the procedure is appropriate, but because it provides valuable information on test application methodologies specific to wet weather assessment requirements;

- *Time-scale issues*

  <u>Response induction time</u>—The response induction time relates to the period of exposure required for an effect to be observed. The rainfall periods driving storm events are frequently of less than 4 hours' duration, producing transient changes in contaminant concentrations in receiving waters that might occur over periods of minutes, with some water quality changes lasting for a day or more. Therefore, intra-event tests need to have exposure regimes that reflect the expected changes in receiving waters. Tests assessing event and long-term time scales will require increasing exposure periods to induce effects.

  <u>Endpoint measurement time</u>—This criterion relates to the time between the event and the test results and is a composite of response induction time and response measurement time.

Tracking capability—Tracking capability relates to the ability of the test system to track an effect through the storm hydrograph. Since wet weather events produce a complex set of exposure concentration, duration, and frequency conditions, an ideal test system for wet weather event assessment must have both rapid response characteristics and some level of independence from exposure history to provide an accurate measure of constantly changing conditions.

- *Measurement issues*

Precision - replicability—Test method replicability is the extent of variability between replicates within the test or replicate determinations on a sample.

Precision - repeatability—Test method repeatability refers to test variability within a laboratory when a series of samples are analyzed by the same operator with the same equipment.

Precision - reproducibility—Test method reproducibility is the extent of the variability in the test between laboratories when the same samples are analyzed.

Sensitivity—The threshold level of response (high sensitivity/low threshold of response; low sensitivity/high threshold of response). Sensitivity has been judged by assessing the minimum concentration of a particular contaminant that will elicit a standardized response (for example EC_{50}/LC_{50}) against a maximum concentration of that contaminant reported in wet weather events (Horner et al., 1994). Increasing sensitivity is shown as the sensitivity index decreases.

Contaminant specificity—The capacity of a measure to respond to specific contaminants typically associated with wet weather events. A method is considered to respond to a particular contaminant if the sensitivity index is less than 1.

Availability of standard method—This criterion relates to the existence of standard methods, standard operating procedures, test guidelines, or published methodologies that, at a minimum, have been subjected to peer review.

Response certainty—Response certainty is related to tracking capability but addresses the degree of certainty that a test response is measured. For example, with an irreversible endpoint, such as death, it is certain that if a response occurs, it will be measured. In contrast, growth could be inhibited by a wet weather event, but the response could be masked if the endpoint is measured some time after the event and the organisms can compensate.

♦ *Ecological relevance*

Ecological relevance of endpoint—This criterion relates to whether the endpoint response measured by the test system can be related to likely effects on populations and communities through direct (or indirect) effects on the growth, reproduction, and survival of individuals.

Ecological relevance: in-stream impact—This criterion assesses whether a relationship can be demonstrated between test system response and measured in-stream impacts.

♦ *Cost*

Cost of implementing the test—Implementation costs cover all the material and time costs associated with equipping and training for test application.

Unit cost of conducting test—The unit cost of a test covers the cost of consumables and the time required for conducting the test.

4.4 Evaluation of Test System Suitability for Wet Weather Event Assessment

The relative importance of each of test selection criteria categories varies according to the time scale within which the test is to be applied. For example, where the time scale of interest is intra-event, analysis of effect over very short time scales is required, and time-scale selection criteria are of prime importance, whereas ecological relevance is less important. In contrast, for long-term, time-scale application, ecological relevance is very important, while the significance of time-scale issues diminishes. Table 4-2 indicates the level of importance of the selection criteria categories for each of the three time scales identified as forming the basis of wet weather event assessments.

Table 4-2. Level of Importance of Test Selection Criteria for Different Time Scales

Selection criteria category	Time Scale		
	Intra-event	Event	Long-term
Time scale	High	Medium	Low
Measurement	Medium	High	High
Ecological relevance	Low	Low	High
Cost	High	Medium	Medium

Consideration of test systems in relation to the importance of selection criteria categories identified in Table 4-2 allows an initial evaluation of the suitability of different test systems to application under the three different time scales. Note that this is intended to be a framework to provide a focus for the assessment of test system suitability. Knowledge of how the test systems operate and are applied are also clearly important considerations. Additionally, overriding considerations, for example cost, might be major forces driving test selection.

Table 4-2 has been used to make a preliminary assessment of the test systems identified earlier as likely to be suitable for wet weather event assessment over different time scales. For example, the evaluation of bacterial bioluminescence (e.g., the Microtox test) against the selection criteria categories for intra-event time-scale assessment is shown in Table 4-3.

Table 4-3. Evaluation of Bacterial Bioluminescence According to Selection Criteria

time scale:	good match	(very low response induction, observation and measurement times, high tracking capability etc.)
measurement:	good match	(high precision and sensitivity)
ecological relevance:	good match	(ecological relevance low but importance of this category is low)
cost:	medium match	(unit cost low but implementation cost high)

Therefore, bacterial bioluminescence appears to be a good candidate for intra-event time-scale application. In contrast, traditional lethality tests used in whole effluent testing, with an induction time of 24 to 48 hours, are inappropriate for this time scale, but could be appropriate for an event time-scale application depending on site specific event time scales. Table 4-4 shows the outcome of an assessment with this approach of the suitability of the range of test systems identified earlier for application under each of the time scales.

The measurement of behavioral responses offers considerable potential for assessing the impact of wet weather events. Techniques that could be applied include those measuring preference-avoidance reactions, abnormal locomotor and reproductive behavior, and altered predator-prey interactions (measured both directly by observation and indirectly through population analysis). However, only automated systems are applicable, since it is not feasible to use systems relying on direct observation because of the unpredictable nature of the onset of wet weather events.

Table 4-4. Preliminary Assessment of Test Suitability for Time-Scale Application

Time Scale	Suitable Test Systems	Unsuitable Test Systems
<u>Intra-event</u> (minutes to hours)	general metabolic enzymes cholinesterase preference/avoidance shell valve closure locomotion in invertebrates heart rate respiration/ventilation rate muscular movement bacterial bioluminescence (acute)	mixed function oxidase cholinesterase heat shock proteins specific stress proteins lethality (lab/field) bioaccumulation feeding rate scope for growth whole body condition index colonization artificial streams enclosures biosurveys
<u>Event</u> (hours to days)	heat shock proteins specific stress proteins lethality (lab/field) preference/avoidance shell valve closure locomotion in invertebrates heart rate respiration/ventilation rate feeding rate scope for growth whole body condition index bacterial bioluminescence (chronic)	general metabolic enzymes cholinesterase activity bioaccumulation muscular movement colonization artificial streams enclosures biosurveys
<u>Long-term</u> (weeks to months)	heat shock proteins lethality (field) bioaccumulation shell valve closure feeding rate scope for growth whole body condition index colonization artificial streams enclosures biosurveys	general metabolic enzymes mixed function oxidase cholinesterase activity specific stress proteins preference/avoidance locomotion in invertebrates heart rate respiration/ventilation rate muscular movement bioluminescence

In the assessment of wet weather events, avoidance responses would seem to offer the greatest potential as test systems. These responses might represent the ultimate early-warning systems of pollutant impact as a result of the action of the substance on the organism's sensory systems. Consequently marked responses might be observed before toxicant uptake and accumulation can result in biochemical and/or physiological effects. However, these systems require a considerable body of background data from which subtle behavioral changes can be discerned.

Preference-avoidance responses of invertebrates and fish species to aquatic pollutants, whether present in the water column or the sediments, have been extensively studied (for reviews, see Heath, 1987). This research has also resulted in the development of a number of automated biomonitoring systems using avoidance responses of aquatic organisms to pollutants.

Positive rheotaxis, whereby fish swim against a current, has been used in a number of automated continuous biomonitors (Baldwin, 1990). Toxicant exposure can lead to a loss of positive rheotaxis and the effects are detected by changes in the position of fish relative to light beams across the test chamber or by the fish touching a grid at the rear of the chamber (for review see Heath, 1987, Baldwin, 1990). For invertebrates, such as *Daphnia*, the effects on phototaxis is used as the response in the system (Knie, 1982; Hendriks and Stouten, 1993). Toxicant-induced effects can result in impaired mobility and an inability to respond to changing physical conditions produced by flow changes.

An avoidance behavior response based on shell-valve activity of freshwater and marine mussels has been developed by Delta Consults in the Netherlands (Kramer, Jenner, and Dezwart., 1989). In the test system, toxicant-induced effects on the valve opening/closing pattern are electronically measured and analyzed.

Automated continuous monitors based on physiological parameters, such as heart rate in invertebrates (Morgan et al., 1987), fish ventilation rate (Baldwin, 1990), and muscular movement (Morgan et al., 1987) have been developed.

4.5 Detailed Test System Selection Methodology

4.5.1 Introduction

The approach developed in Section 4.4 provides a general framework for assessing the suitability of a given test to application within each of the three wet weather assessment time scales. In some cases, it is desirable to undertake a more detailed and objective test selection process to choose the most appropriate of those tests identified as suitable for a given time-scale application. To this end, a detailed, objective test selection methodology has been developed, based on qualitative and semi-quantitative assessments of test performance against the individual test selection criteria.

In outline, the test selection procedure involves assessing tests against the criteria identified in Section 4.3, then assigning scores for each criterion and summing the scores to obtain a total score for each test. Since the procedure has guidelines for assigning scores, the tests can be compared in an objective manner to identify those most suited to the required role. Weighting factors have also been developed to reflect (a) the perceived importance of each criterion for assessing wet weather events and (b) the requirements of each of the two tiers of testing.

4.5.2 Score Bandings for Test Selection Criteria

For each of the test selection criteria, five qualitative or semi-quantitative score bands were developed, reflecting progressively better performance of the actual test characteristic against the optimum for the criterion. The bands were allocated scores from zero (worst) to four (best).

Optimum test characteristics vary slightly, depending on the time scale that is of interest. Consequently, the score bandings differ for some of the selection criteria for the different test application time scales (intra-event, event, long-term). In a few cases, criteria are not relevant or not applicable to one or more time scales; in others, different values in the score bandings reflect the differing requirements. The score bandings for each time scale are presented in Tables 4-5 to 4-7.

4.5.3 Weightings

The final component of the test system selection methodology is different sets of weightings for the screening or confirmatory tiers. The weightings follow the rationale developed in Section 4.4 and illustrated in Table 4-2 that for a given time scale, different categories of test selection criteria have different levels of importance. Here, this theme has been developed further to produce individual weightings for each of the test selection criteria. Separate sets of weightings were developed for different testing tiers, to reflect the differing test requirements. For example, ecological relevance is more important for a confirmatory test than it is for a screening test.

Table 4-5. Score Bandings for Intra-Event Time-Scale Test Selection Criteria

Criterion	Score					Notes
	0	1	2	3	4	
Previous application to wet weather events	none	1 study	>1 study	10 studies	25 studies	
Response induction time	>4 hours	≤4 hours	≤1 hour	≤15 min	≤5 min	
Endpoint measurement time	>10 days	≤10 days	≤5 days	≤2 days	≤1 day	working days
Tracking capability	irreversible response	non real time on/off	non real- time tracking	real-time on/off	real time tracking	
Ecological relevance of endpoint	relevance unknown	response correlated with individual response	individual response, relevance unknown	individual response related to population/ community fitness	population/ community response	Individual response relates to growth, reproduction and lethal effects in test species
Ecological relevance - in-stream impact	no relationship	-	-relationship established		direct measure of instream impact	
Precision - replicability	>40%	≤40%	≤30%	≤20%	≤10%	coefficient of variation
Precision - repeatability	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Precision - reproducibility	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Sensitivity	>1.0	≤1.0	≤0.5	≤0.1	≤0.01	Standardized test response, max. ww event concentration.
Contaminant specificity	0	1	2-4	5-7	8-9	number of contaminant types test responds to at defined sensitivity
Standard method available	none	no SOP but documented method	no SOP but preferred method	SOP, non-ring tested	Ring-tested SOP available	
Response certainty	completely and rapidly reversible, no record	reversal of response rapid in relation to test duration, no record	reversal of response slow in relation to test duration, no record	irreversible response, no record	real time or pseudo-real time record	'record' refers to capture of data during a storm. Laboratory test on water samples collected through a storm would score 4.
Cost of implementing test	>$20000	≤$20000	≤$10000	≤$5000	≤$2000	
Unit cost of conducting test	>$1000	≤$1000	≤$500	≤$250	≤$100	

Table 4-6. Score Bandings for Event Time-Scale Test Selection Criteria

Criterion	Score					Notes
	0	1	2	3	4	
Previous application to wet weather events	none	1 study	>1 study	10 studies	25 studies	
Response induction time	>48 hours	≤48 hours	≤24 hours	≤12 hours	≤4 hours	
Endpoint measurement time	>10 days	≤10 days	≤5 days	≤2 days	≤1 day	working days
Tracking capability						NOT APPLICABLE
Ecological relevance of endpoint	relevance unknown	response correlated with individual response	individual response, relevance unknown	individual response related to population/ community fitness	population/ community response	Individual response relates to growth, reproduction and lethal effects in test species
Ecological relevance - in-stream impact	no relationship	-	-relationship established		direct measure of instream impact	
Precision - replicability	>40%	≤40%	≤30%	≤20%	≤10%	coefficient of variation
Precision - repeatability	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Precision - reproducibility	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Sensitivity	>1.0	≤1.0	≤0.5	≤0.1	≤0.01	Standardized test response, max. ww event concentration.
Contaminant specificity	0	1	2-4	5-7	8-9	number of contaminant types test responds to at defined sensitivity
Standard method available	none	no SOP but documented method	no SOP but preferred method	SOP, non-ring tested	Ring-tested SOP available	
Response certainty	completely and rapidly reversible, no record	reversal of response rapid in relation to test duration, no record	reversal of response slow in relation to test duration, no record	irreversible response, no record	real time or pseudo-real time record	'record' refers to capture of data during a storm. Laboratory test on water samples collected through a storm would score 4.
Cost of implementing test	>$20000	≤$20000	≤$10000	≤$5000	≤$2000	
Unit cost of conducting test	>$1000	≤$1000	≤$500	≤$250	≤$100	

Table 4-7. Score Bandings for Long-Term Time-Scale Test Selection Criteria

Criterion	Score					Notes
	0	1	2	3	4	
Previous application to wet weather events	none	1 study	>1 study	10 studies	25 studies	
Response induction time						NOT APPLICABLE
Endpoint measurement time	>30 days	≤30 days	≤20 days	≤10 days	≤5 day	working days
Tracking capability	irreversible response	non real time on/off	non real- time tracking	real-time on/off	real time tracking	
Ecological relevance of endpoint	relevance unknown	response correlated with individual response	individual response, relevance unknown	individual response related to population/ community fitness	population/ community response	Individual response relates to growth, reproduction and lethal effects in test species
Ecological relevance - in-stream impact	no relationship	-	-relationship established		direct measure of instream impact	
Precision - replicability	>40%	≤40%	≤30%	≤20%	≤10%	coefficient of variation
Precision - repeatability	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Precision - reproducibility	>100%	≤100%	≤60%	≤30%	≤10%	coefficient of variation
Sensitivity	>1.0	≤1.0	≤0.5	≤0.1	≤0.01	Standardized test response , max. ww event concentration.
Contaminant specificity	0	1	2-4	5-7	8-9	number of contaminant types test responds to at defined sensitivity
Standard method available	none	no SOP but documented method	no SOP but preferred method	SOP, non-ring tested	Ring-tested SOP available	
Response certainty	completely and rapidly reversible, no record	reversal of response rapid in relation to test duration, no record	reversal of response slow in relation to test duration, no record	irreversible response, no record	real time or pseudo-real time record	'record' refers to capture of data over a period of time
Cost of implementing test	>$20000	≤$20000	≤$10000	≤$5000	≤$2000	
Unit cost of conducting test	>$1000	≤$1000	≤$500	≤$250	≤$100	

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Weightings have been developed for intra-event time-scale tests only, and these are shown in Table 4-8. This time scale of assessment is where time scale of test response is most critical and where test requirements are consistent and independent of study objectives and site-specific factors. For event and long-term time scales of assessment, study objectives, site, and watershed-specific factors become more important in determining the relative importance of test selection criteria. For example, site-specific factors that include best management practice (BMP) presence, issues of concentration time, or hydrograph characteristics determine which time span is appropriate for event analysis. Watershed-specific factors require consideration of both spatial and temporal scale issues, often requiring multiple locations and multiple or sequenced sampling to provide useful long-term assessment results. The weightings are applied by multiplying a test's score for each of the criteria by the weighting factors appropriate for the tier of interest to give a weighted score. The weighted scores are then summed to give a total score that can be compared with that for other tests.

Table 4-8. Weighting Factors for Intra-Event Test Selection Criteria

Criterion	Weighting factor		
	Basic screening tests	Advanced screening tests	Confirmatory tests
Previous application to wet weather events	3	3	3
Response induction time	5	5	5
Endpoint measurement time	4	3	1
Tracking capability	5	3	3
Ecological relevance of endpoint	1	3	5
Ecological relevance - in-stream impact	1	3	5
Precision-replicability	3	5	5
Precision – repeatability	3	4	5
Precision – reproducibility	3	3	4
Sensitivity	4	5	5
Contaminant specificity	4	4	4
Standard method available	2	4	4
Response certainty	2	4	5
Cost of implementing test	5	3	3
Unit cost of conducting test	5	3	3

4.6 Example Application of Test System Selection Methodology

The test system methodology was applied to a range of tests from the candidate tests listed in Section 4.2 for the intra-event time scale to ascertain which tests were most likely to be suitable for deployment in a test battery. Table 4-9 shows the weighted scores for potential intra-event time-scale basic screening tests.

The assessment of methods which can be applied to a wide range of species has focused on standard WET testing species, such as *Ceriodaphnia dubia*, *Hyalella azteca*, and *Pimephales promelas*, since these species are widely available, and the same screening methods should be applicable across regions. From the data, it was evident that only a limited number of cost-effective techniques had response induction and measurement times matching the time scales of exposure required for intra-event analysis, combined with a high tracking capability. Only general metabolic enzymes (such as the inhibition of β-galactosidase activity used in the inhibitory quotient test) and bacterial bioluminescence met these criteria with both tests having scores of 58% and higher.

The behavioral assays (such as preference/avoidance, shell valve closure, and locomotion in invertebrates) and physiological responses (such as heart and respiration/ventilation rates and muscular movement) can provide rapid responses, but the systems cab be affected by physico-chemical changes associated with wet weather events (such as changes in temperature, conductivity or suspended solids) rather than toxicity. Changes in dissolved oxygen, which might be of significance in terms of receiving system impact, can also elicit responses in these tests.

Behaviorally-based automatic monitoring systems, such as those using locomotion in daphnids (Knie, 1982) and fish (Baldwin, 1990) and shell-valve closure in mussels can provide continuous data in real or pseudo real time. The methodology involved in the automated monitors is sometimes complex, and the capital investment required to purchase these monitors is generally high. Furthermore, the relationships between the test endpoint and ecologically relevant parameters is usually uncertain.

The use of clams or mussels is possible with commercially available products (e.g., Mussel Monitor), and these systems have proven reliable and robust. Fish monitors require considerable time for operation, covering fish husbandry, calibration, and maintenance. Nonetheless, the need for continuous monitoring at certain locations might justify the high cost.

Table 4-9. Weighted Scores for Candidate Basic Screening Test Systems for Intra-Event Time-Scale Assessment

Criterion	Microtox	*C. dubia* IQ	Locomotion in invertebrates	Valve position in clams or mussels	Ventilation frequency in fish
Previous application to wet w. events	6	0	0	3	3
Response induction time	20	10	20	20	20
Endpoint measurement time	16	16	16	16	16
Tracking capability	10	10	20	20	20
Ecological relevance of test endpoint	1	1	0	0	0
Ecological relevance - instream impact	0	0	0	0	0
Precision-replicability	12	12	N/A	N/A	N/A
Precision – repeatability	9	9	ID	ID	ID
Precision – reproducibility	9	ID	ID	ID	ID
Sensitivity	16	8	ID	16	ID
Contaminant specificity	8	4	ID	8	ID
Standard method available	6	6	4	4	4
Response certainty	8	4	8	8	8
Cost of implementing test	5	15	0	0	0
Unit cost of conducting test	20	20	10	10	5
TOTAL SCORE	146	115	78	105	76
(% of maximum score)	(73%)	(58%)	(39%)	(58%)	(38%)

ID - insufficient data, N/A - not applicable

Although traditional lethality tests of 24 to 48-hour duration are inappropriate for intra-event testing, previous studies (Abel, 1980a, b; Abel, and Gardner 1986; Jarvinen, Tanner, and Kline, 1988) have shown that episodic exposure (that is short-term contaminant exposure (<4 h) followed by exposure to non-contaminated conditions) can cause significant lethality. Therefore, research has been carried out to assess the usefulness of modified lethality-based tests with standard WET test organisms that are appropriate to the intra-event time scale (see Chapter 5.0).

CHAPTER 5.0

SUMMARY INFORMATION ON METHOD DEVELOPMENT AND APPLICATION

5.1 Introduction

In the previous chapter, a series of key test selection criteria, based on both wet-weather event assessment and general testing requirements, was developed. Two of the key criteria were: (1) previous application to wet weather events; and (2) time scale of response criteria. Unfortunately, these criteria were seldom met, particularly for test application at the intra-event . This indicated a need for development of methods for time-scale based approaches to toxicity assessment.

The shortfall in existing test systems reflects the fact that they were largely developed for assessment of continuous exposure to contaminants, through an organism-based approach. As identified earlier, the requirements for assessment of episodic exposure to contaminants, as in wet-weather events, demand a time scale of response approach. Table 5-1 summarizes the key differences between the two approaches required for assessing continuous and episodic events.

As part of this project, research was initiated to develop or modify testing, analysis, and interpretation methods to support time-scale analysis and to fill the shortfall in existing testing or analysis systems. Methods developed are outlined in this chapter and described in detail in Appendix B. This research also involved an extensive field program that incorporated assessments ranging from analysis of samples from storm events to in situ exposure of organisms and watershed focused bioassessments.

Table 5-1. Differences Between Continuous and Episodic Event Assessment Approaches

Characterization	Continuous exposure	Episodic exposure
Exposure regime	• continuous exposure to contaminants (concentration might fluctuate)	• intermittent exposure to contaminants, with fluctuating concentrations during exposure (BMP may even out fluctuation)
Test regime	• organism-based approach • standard tests (WET)	• "time scale of response" approach • modified tests (time scale to match exposure time)
Sampling regime	• site specific • can target toxicity variability • long-term composite samples appropriate	• storm driven • focus on concentration or toxicity peaks • intra-event analysis requires time-sequenced or flow-weighted grab samples (composites for longer events) • event sampling requires time- or flow-weighted composites

5.2 Time-Scale Toxicity

5.2.1 Introduction

As discussed in Chapter 2.0, existing standard methodologies for toxicity testing generally rely on test systems that operate on time scales that are not appropriate for the full range of time scales required for wet-weather event analyses. A major thrust of this project was to evaluate new methods and adapt existing standard methods to the shorter time-scales of relevance to wet-weather intra-event assessment.

Laboratory experiments were conducted to investigate the effect of short (or pulse) exposures to a range of contaminant concentrations. These concentrations provided a wide range of exposures, including some concentrations that are higher than might be expected in wet-weather discharges. These toxicity experiments were not intended to represent the full complexity of wet weather discharges, rather they were designed to assess short exposure effects using contaminants known to occur in stormwater runoff. The exposure method placed test organisms in a test solution for different time periods (up to 240 minutes) and then removed the organisms to clean water for post-exposure observation. These experiments focused on lethal effects but also included sublethal effects, such as reproduction, enzyme inhibition, and growth. Table 5-2 shows a summary of the range of experiments performed. Contaminant concentrations used were multiples of experimentally-developed 24-hour LC_{50} concentrations. Organism responses were compared between species, between contaminants, and between differing stock cultures and laboratory facilities. The research then attempted to connect the results to actual episodic pollution events, through the sampling and analysis of urban stormwater runoff events.

5.2.2 PE-LET_{50}

5.2.2.1 Determination

A new test and metric for the analysis of time-scale toxicity was developed and applied. The proposed Post-Exposure Lethal Exposure Time for 50% of the population (PE-LET_{50}) adapts the LT_{50} (or time to death) test methodology specifically to the analysis of episodic pollution events. The PE-LET_{50} test, like the LT_{50} test, uses the exposure duration as the test variable; however, the PE-LET_{50} test used for stormwater analysis attempts to adjust test exposure duration to more closely match those of the event. Since episodic pollution events are typically brief (on the order of hours to days), and the duration of pollutant transients during the event are much shorter (minutes to hours), the PE-LET_{50} test procedure uses short exposure durations. When short-exposure durations are used, it is also necessary to incorporate post-exposure observation, for it has been found that short exposures to toxicants can delay effects or allow organism recovery (Abel, 1980a, b; Abel and Gardner, 1986; Jarvinen, Tanner, and Kline, 1988).

The proposed PE-LET_{50} test exposes test organisms to a sample of stormwater, similar to the effluent sample used in a whole effluent test. Typically, several grab samples are collected during an event and exposure times in the test adjusted to sample/event characteristics to provide short exposures (on the order of minutes to hours). After the allotted exposure duration, test organisms are removed and placed in clean water and observed during a post-exposure period. The post-exposure period is long enough to observe the ultimate effect of all samples. Data are then analyzed to obtain the exposure duration that produces the median lethal response in the post-exposure period, the PE-LET_{50}. The PE-LET_{50} is the exposure time necessary to produce 50% lethality of the test population at the end of the post-exposure observation period. The PE-LET_{50} is similar to the LT_{50} metric, yet the exposure durations are discrete, short, and response measured at the end of a post-exposure period. The PE-LET_{50} is compared to other common metrics in Table 5-3.

Table 5-2. Summary of Supplemental Time-Scale Toxicity Experiments Performed

Species	Location	Substance	Concentrations (mg/L)	Exposure Durations (min)	Endpoints Measured
H. azteca	UIUC	Cd	0.06, 0.19, 0.4, 0.6, 1.0, 1.9	15, 30, 60, 120, 180, 240	lethality
		Zn	2.0, 6.4, 13.34, 20, 33.3, 64	15, 30, 60, 120, 240	lethality
	UNT	Cd	0.06, 0.19, 0.4, 0.6, 1.9	15, 60, 240	lethality
C. dubia	UIUC	Cd	0.37, 1.18, 2.5, 3.7, 6.0, 11.84	15, 30, 60, 120, 240	lethality, reproduction, enzyme inhibition
		Zn	0.15, 0.4, 1.0, 1.5, 2.5, 4.8	15, 30, 60, 120, 240	lethality
		Phenol	10, 32, 66.7, 100, 167, 320, 500	15, 30, 60, 120, 240	lethality
	UNT	Cd	0.37, 1.18, 2.5, 3.7, 6.0, 11.84	15, 30, 60, 120, 240	lethality
P. promelas	UIUC	Cd	0.4, 1.28, 2.67, 4.0, 6.67, 12.8	15, 30, 60, 120, 240	lethality, growth

UIUC = University of Illinois, Urbana-Champaign, UNT = University of North Texas.

5.2.2.2 Application

A series of experiments was performed with cadmium and zinc to develop the PE-LET_{50}.testing and ansylsis procedures. These tests revealed that following short Cd and Zn exposure, effects increased during the post-exposure period as evidenced by PE-LET_{50} values that decreased asymptotically with increasing post-exposure measurement time. The asymptotic value approached by the PE-LET_{50} is termed the ultimate PE-LET_{50}, or the exposure duration that ultimately produces a 50% lethal effect. As the post-exposure measurement time increased, the measured PE-LET_{50} value more closely approximated to the ultimate value. PE-LET_{50} values stabilized at 24 to 96 h post-exposure. In general, the 48-h PE-LET_{50} closely approximated the ultimate PE-LET_{50} value.

Table 5-3. Comparison of PE-LET_{50} Metric to Other Metrics in Use or Proposed for Use

Metric	Test conditions	Test characteristic measured	Information provided
LC_{50}	Continuous exposure to range of concentrations	Lethality at end of set duration exposure	The concentration necessary to produce a lethal response within a set duration
LT_{50}	Continuous exposure to single concentration	Lethality at set times during exposure	The speed of a toxic response
pe-LT_{50}	Single concentration exposure, with subsequent post-exposure observation	Lethality at set times during post-exposure observation	The post-exposure time necessary to observe lethality
20-day LT_{50}	Single concentration exposure for a range of exposure durations, with subsequent post-exposure observation	Lethality at 20 days post-exposure	The exposure time required to produce lethality within 20 days
PE-LET_{50}	Single concentration exposure for a range of exposure durations, with subsequent post-exposure observation	Lethality at set times during post-exposure observation	The exposure time necessary to ultimately produce lethality

Figure 5-1 shows an example plot of PE-LET_{50} values for *H. azteca* exposed to cadmium. Further detail on the application of the method can be found in Appendix B.

5.2.3 Event Toxicity Unit

5.2.3.1 Determination

The PE-LET_{50} toxicity test assesses the toxicity of an individual sample collected during an episodic pollution event in units of time (the time of exposure to the sample necessary to produce a 50% effect during a set post-exposure period). If the level of toxicity (and therefore the PE-LET_{50} value) during the event was constant, then the toxicity of the entire event could be quantified as a ratio of the event duration to the PE-LET_{50} value of a sample from the event. This ratio would be a dimensionless parameter that relates the duration of the event to the exposure duration necessary to produce a 50% lethal effect, the PE-LET_{50}. A ratio of exactly one would indicate that the duration of the event was equal to the duration of exposure necessary to produce a 50% effect. A ratio greater than one indicates that the event would be expected to produce >50% effect in the test population. A ratio less than one indicates that the event did not produce exposure conditions (toxicity, duration, or combination of both) necessary to produce a 50% effect. This parameter would increase with increasing event duration and with increasing magnitude of event toxicity (measured by the PE-LET_{50}).

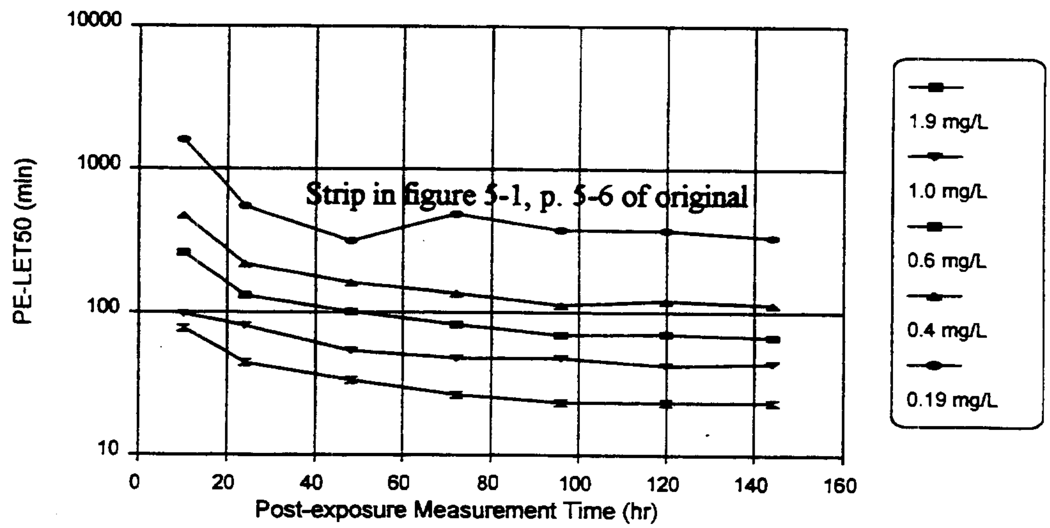


Figure 5-1. Change in PE-LET_{50} over Time for *H. azteca* Cd Exposure

The level of toxicity during episodic events, however, is not constant, and the PE-LET_{50},therefore,varies with time throughout the event. To obtain the same useful time/PE-LET_{50} ratio in this case, the PE-LET_{50} must be defined as a function of time. This is done by performing PE-LET_{50} testing on samples collected sequentially throughout the event. The time/PE-LET_{50} ratio is then derived in this case by integrating the function 1/PE-LET_{50} over time. This ratio has been termed the event toxicity unit (ETU). Figure 5-2 shows an example ETU calculation.

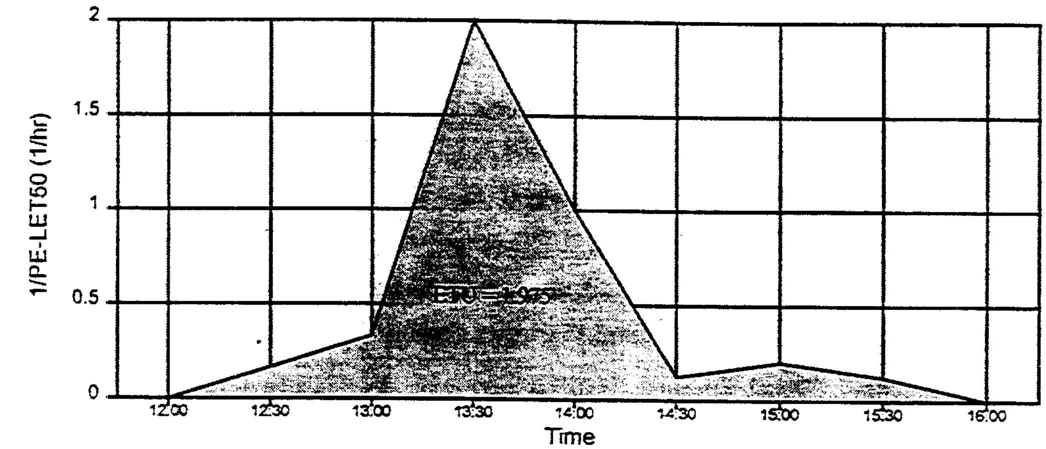


Figure 5-2. Example Calculation of an Event Toxicity Unit (ETU)

The benefit of the ETU is that it is a quantitative measure of total event toxicity. It incorporates both the duration and magnitude of event toxicity. It allows comparison of events that differ in duration, intensity, and sequence of toxic conditions. The ETU analysis does not require a detailed knowledge of contaminant concentrations throughout the event. Furthermore, ETU can also compare actual event conditions with reference exposure situations of known toxicity.

5.2.3.2 Application

ETU analysis was applied to a series of time-varying concentrations of Cd and Zn. Sixteen exposure regimes, including Cd and Zn exposures that varied in concentration and duration, were tested. All exposures consisted of three sequential exposures to varying concentrations of Cd and/or Zn for varying durations. Of the sixteen exposure scenarios, ETU values ranged from 0.42 to 1.81.

ETU analysis was also performed on samples collected from urban stormwater discharge events in Texas and Ohio. Samples were collected from a storm sewer that drains a 48-acre urban/industrial area of Fort Worth, Texas, that is a tributary of the Trinity River. Samples from this site were collected at 30-minute intervals during a four-hour storm event. Samples were also collected from a stream in Ohio that drains a highly devleoped, although predominantly suburban, watershed of approximately 11,600 acres. At this site, time-composited samples were collected during an extended storm event. Sub-samples were collected every 15 minutes for six hours, comprising a single composite. Four composite samples were available for each 24-hour period.

For the Texas site, the PE-LET_{50} values were calculated for six samples that showed significant toxicity in screening tests. Other samples during the event that showed little or no toxicity in 48-h screening tests were assumed to have very high PE-LET_{50} values and, therefore, the 1/PE-LET_{50} value approached zero. The ETU for this storm was 0.98, indicating that the toxicity was at a level expected to cause 50% lethal effect to *C. dubia*. The toxicity results for the Ohio site produced an ETU of 3.28. This event surpassed the magnitude and duration necessary for 50% lethal effect by more than a factor of three. It should be noted that even though the degree of toxicity in the Texas samples was greater than that in samples from the Ohio site (based on 1/PE-LET_{50} values), the severity of the Ohio event was much greater due to the longer duration of the event.

5.3 Basic Screening Test Evaluation

5.3.1 Introduction

A major criterion for time-scale toxicity analysis is the response time of the test system, in particular the need for a test to respond to the short time scales of exposure in stormwater discharges. Two test systems were evaluated as additional basic screening tools in time-scale toxicity analysis, the "IQ" test using *Ceriodaphnia dubia* and the Microtox assay.

5.3.2 *Ceriodaphnia dubia* IQ Test

The "IQ" assay is an inhibition quotient assessment, which measures activity of the enzyme β-galactosidase. Test organisms are fed an enzyme substrate, which is cleaved by the enzyme, producing a fluorescent product. The degree of fluorescence, therefore, is a measure of enzyme activity. The time required for response induction is approximately 15 minutes. Testing conducted with *Ceriodaphnia dubia* showed activity was generally inhibited directly following the exposure period, yet enzyme activity was restored during the following 48 hours. The maximum percent effect generally increased with increasing exposure times and with increasing Cd concentrations. The mean time of maximum enzyme inhibition was 3.30 hours (with a 95% confidence interval of 2.65 to 3.96) after the onset of exposure. Since several of the exposure times were less than 3 hours, often the maximum percent effect was not reached until after the exposure period had ended. For these very short exposure periods, the enzyme inhibition was actually lower directly after the exposure period, reached a maximum approximately 2 to 4 hours later, and then again decreased as the organisms recovered. This time gives some indication of the total time for the transfer of toxicants to the site of action and response manifestation—an important benefit of the IQ assay in time-scale toxicity.

5.3.3 Microtox Assay

A common finding of Microtox assays of stormwater samples was the occurrence of stimulation rather than the expected inhibition of bioluminscence, and this issue was investigated to determine the possible cause. These investigations indicated that the stimulation observed could be due to hormesis—a stimulation occurring as a result of exposure to mild toxicity. Hormesis has been documented repeatedly (Stebbing, 1982), although it is not fully understood.

Analysis of stormwater samples in this study produced a reasonably consistent stimulation in the Microtox assay. The consistency of response suggested a more detailed examination of low concentration response with the Microtox assay would provide sufficient information to identify an increased sensitivity of response not previously reported. A series of studies was initiated to evaluate stimulation/hormesis in the Microtox assay. Six metal contaminants (Cd, Cr, Cu, Pb, Ni, and Zn) along with phenol and sodium lauryl sulfate were tested using procedures consistent with screening level testing used in this project.

The experiments supported the conclusion that it is possible to quantify stimulation at low exposure levels, and, for several contaminants, a concentration-response relationship could be identified for the range of exposure concentrations. It was also apparent from this research that the frequency and magnitude of induced stimulation was affected by several factors. Some contaminants produced more stimulation than others, particularly Cr and the organic compounds, phenol and sodium lauryl sulfate. When the stimulation levels observed in these experiments were compared with stimulation levels observed in stormwater sampling, no single contaminant produced maximum stimulation levels observed in stormwater (up to 60%). Further testing with binary mixtures and simulated stormwater confirmed the utility of using the stimulation response in the Microtox assay as a basic screening response in time-scale toxicity analysis.

5.4 Advanced Screening Tools

5.4.1 Introduction

The time-scale toxicity testing protocol adopted in this research initially calls for basic screening tests, then application of advanced tier testing to confirm toxicity and address issues of impact, source identification, and management options. In this research, advanced tier testing uses advanced screening tools to complement basic screening tools. However, the advanced tools do not necessarily address all concerns that would be addressed by advanced tier testing in a typical hazard evaluation. The following discussions review a number of advanced screening tools evaluated as a part of this research. These tools range from advanced toxicity screening tools, such as toxicity identification evaluation (TIE), to the application of sewer models to assist in both identifying sources of contaminants and defining approaches to sampling sewers based on source location and flow concentration time. A number of advanced screening tools, including toxicity testing and analysis schemes and other methodologies, have been developed or evaluated in this research to identify sources and causes of toxicity (Figure 5-3).

5.4.2 Watershed Modeling—Storm Sewer Model

A watershed focus in time-scale toxicity testing incorporates the sense of land use and location in application of the time-scale toxicity assessment protocol. In urban watersheds, one of the factors that can alter fundamental watershed characteristics is the presence of storm sewers. Storm sewers, by design, collect runoff from areas where land use and other activities might influence its quality and deliver it to a single location. Fortunately, sewers have been the focus of modeling efforts around the world so it is possible to predict the dynamics of sewer flow in a way that assists in time-scale toxicity assessments. For example, the sewer model can accurately predict concentration times for flows from different areas of the watershed. Using this information, it is possible to connect a sewer model with time-sequenced sampling at the discharge to identify possible sources of toxicity/contamination.

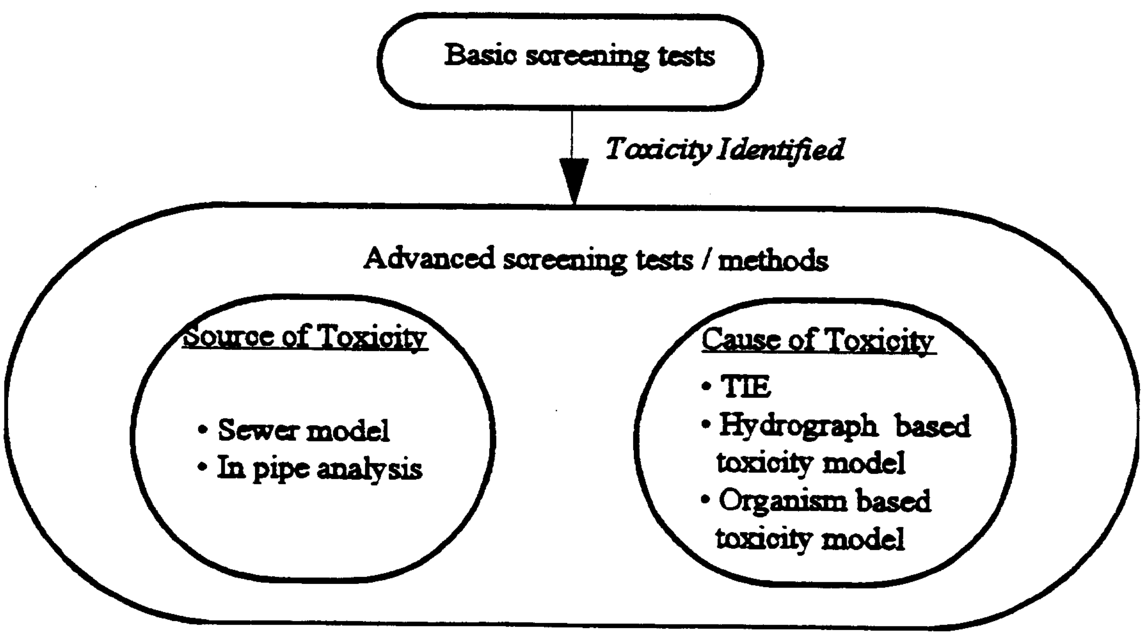


Figure 5-3. Advanced Screening Tools

Application of an available model is often a compromise between detail and availability of model input and the expected use of model output. As this project evolved from a focus on in-stream analysis of time-scale toxicity to include in-pipe and near-outfall assessment, a need developed to model outfall hydrology to assist in both interpretation of toxicity during storm events, and prediction of toxicity as affected by storm sewer system characteristics. The focus on the Kaufman Lake Storm Sewer (KLSS) required an analysis of the sewer "tributary" system to identify possible sources of contaminants. Furthermore, modeling suggested itself as a means to supplement toxicity testing with information on sewer dynamics that would assist in developing contaminant source and frequency and duration of exposure information.

The most widely used model for this type of analysis is the Stormwater Management Model (SWMM). Unfortunately, SWMM is a complex model that requires input data detail that was not readily available for this project. A second model, the Illinois Urban Drainage Area Simulator (ILLUDAS) was developed locally, had minimal input data requirements, and was supported locally. ILLUDRAIN (Ver 2.10) was applied to the KLSS system. Model sensitivity was tested for different antecedent moisture condition (AMC) for several storms. The effect of rainfall amount was investigated using three storms, the one-year, two-hour rainfall, a moderate storm event, and a storm of low intensity. The application of ILLUDRAIN found that the model is sensitive to the percent grassed area in a watershed. Further, the model provides an option for identifying local surface hydrographs. The local hydrograph was found to be useful in identifying potential sources of contaminants by relating contaminant concentrations observed to the concentration time associated with watershed locations.

5.4.3 Toxicity Modeling

5.4.3.1 Introduction

Literature reports and observations made during field testing on this project and a general analysis of contaminant/hydrograph relationships identified through the literature review suggest that toxicity during a storm-related hydrograph should be predictable. To this end, a simple predictive model of site-specific receiving system toxicity associated with storm events was developed. The model was used to assess the expected toxicity of heavy metals in receiving systems. This simplified model did not predict metal speciation or the presence of biologically available metal concentrations. The model simply related expected change in concentration to toxic potential based on published criteria.

5.4.3.2 Hydrograph-Based Toxicity Model

The underlying concept for the development of this model was that it was possible to use regional hydrologic information to describe hydrograph characteristics. Further, it was possible to translate expected contaminant concentration into a toxicity unit (TU) and provide an additive estimate of event toxicity. The model completes an estimation of a hydrograph from a partial specification of hydrograph characteristics. On the basis of this projection and estimates of contaminant input, the model then estimates the expected stream toxicity during runoff events. The hydrograph is a function of the total available overland flow supply, subsurface flow, groundwater flow, slope of the overland and stream segments, and geometry of channels, which can be separated into two elements, a rising limb and a recession limb. To convert predicted or actual contaminant concentrations to effect estimates the toxic unit (TU) defined by the US EPA (1991) was used. A TU is "a measure of toxicity in an effluent as determined by the acute toxicity units or chronic toxicity units measured" and is simply a reciprocal of the LC_{50} or the no observable effect concentration (NOEC). In this model, the acute toxicity unit based on published criteria was used.

An initial model predicted TU values for only one contaminant where TU values were required as model input. The model was modified to allow prediction for five contaminants typical of stormwater discharges (Pb, Cr, Cd, Zn, and Cu), which used the concentration of a contaminant as an input value, not a specified TU. The model did not account for physical or chemical factors that affect biological availability of metals; it simply predicted the toxicity of metals based upon concentrations reported in the literature as being toxic. The revised model calculates a cumulative toxicity using a simple additive assumption and added the ability to model storm events that produce multiple peaks.

The model was used as a tool to assist in developing a conceptual base for time-scale toxicity analysis. For example, a first flush might be expected to produce an initial peak in toxicity followed by a rapid decrease and low levels of toxicity in the remainder of the storm event. Another possible time-scale toxicity scenario finds a second peak of toxicity in a storm event when previously deposited contaminants are resuspended in the water column. When evaluated against storm event monitoring data, the presence of a first-flush-related toxicity was confirmed. Monitoring also confirmed toxicity later in the hydrograph. The model continues to be useful in providing a "what if" analytical tool to determine what changes are needed in initial assumptions to assist in interpreting possible causes of an observed time-scale toxicity result for a storm event.

5.4.3.3 Organism-Based Toxicity Model

Many toxicity models appearing in the literature are based on first-order kinetics of toxic uptake and depuration. These models commonly represent the organism as a single compartment that can ingest, store, and excrete a toxicant. According to this type of model, a toxic endpoint, such as mortality, occurs when the tissue concentration reaches a critical concentration. LC_{50} predictions are based on uptake and depuration rates obtained from the literature or experimental data.

The model developed as a part of this research was used to predict toxic effects resulting from time-variant Zn concentrations. To test this application, the model was applied to data obtained from the Fort Worth field campaign in May, 1995. The model predicted significant Zn toxicity at the industrial site based on predicted total Zn accumulation. These results are also consistent with the ETU value of 1.05, which would indicate a highly toxic event.

CHAPTER 6.0

STUDY SITE SUMMARY INFORMATION

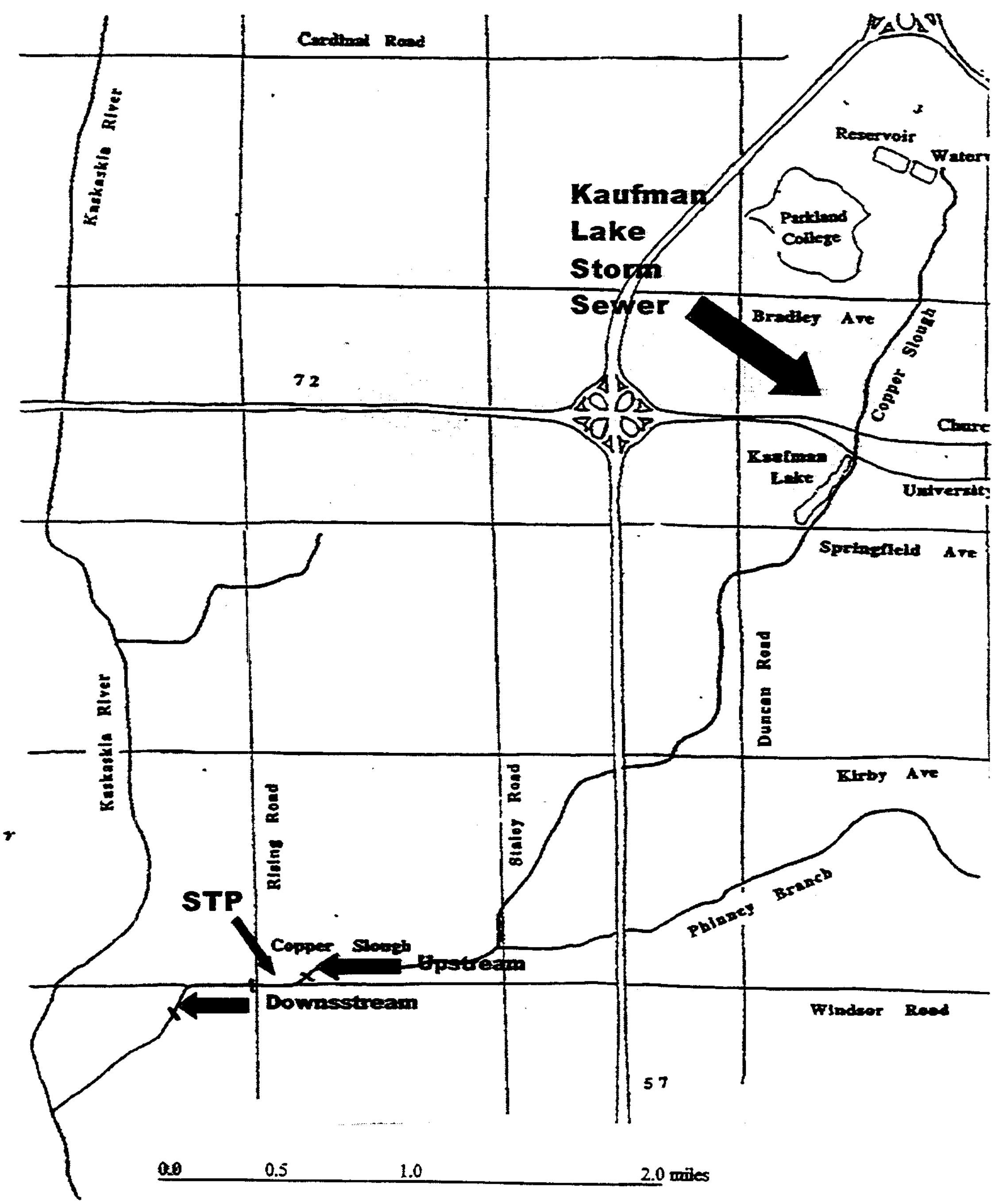
6.1 Introduction

This chapter provides information on the project study sites. The main site was the Copper Slough Watershed near Champaign, Illinois. Regional study sites were the Trinity River Watershed in Fort Worth, Texas, and the Cuyahoga River Watershed near Cleveland, Ohio. In-pipe samples were obtained from the Kaufman Lake Storm Sewer (KLSS) in the Copper Slough watershed and at three locations on the Trinity River watershed (Cra, Eastern Hills, and Pylon). Receiving water samples were taken from the Copper Slough, Sycamore Creek (a tributary to the Trinity River in Fort Worth, Texas), and Mill Creek (a tributary to the Cuyahoga River in Cleveland, Ohio).

6.2 Copper Slough Watershed

The Copper Slough is a tributary of the Kaskaskia River near Champaign, Illinois. The Copper Slough watershed has been the subject of detailed hydrologic, geomorphic, and fisheries analyses for several years and was a National Urban Runoff Program (NURP) study site. The Copper Slough drainage area is approximately 41 km^2. Land use in the watershed is about 40% urban and 60% agricultural. The stream originates in the northwest corner of the City of Champaign, flows through a predominantly urban area for approximately 2 km, and then flows through agricultural and suburban areas to its confluence with the Kaskaskia River. A number of storm sewer outfalls enter the Copper Slough in the upstream, urbanized area. Downstream, the Copper Slough is influenced by a sewage treatment plant (STP) outfall and urban and agricultural runoff. Two main study sites were located in the Copper Slough watershed (Figure 6-1). The first study site was associated with the Urbana-Champaign Sanitary District Southwest Sewage Treatment Plant in the lower Copper Slough watershed, approximately 1 km upstream from the Copper Slough, Kaskaskia River confluence. The second study site was the KLSS System, located in an upstream area of the Copper Slough watershed, approximately 4 km upstream from the STP site.

Figure 6-1. Copper Slough Watershed



6.2.1 STP Study Locations

Field studies were initiated in the Copper Slough Watershed in 1994 focusing on downstream (STP) study locations. Two stations were chosen that represented receiving system, multiple discharge conditions. One was located 100 m below the STP, called "downstream (DS)" herein. The DS location was selected as a maximum impact station, subject to normal stormwater flows and combined sewer overflows (the chlorinated, primary treatment effluent occurring during major storm events). A second station approximately 100 m upstream from the STP outfall, called "upstream (US)" herein, was selected to provide an indication of urban and agricultural stormwater effects in the absence of STP discharges. Summaries of storm events assessed at these stations are provided in Tables 6-1 and 6-2.

Sampling at the downstream locations included time sequenced water sampling, artificial substrate sampling for macroinvertebrates, in situ deployments of invertebrates and fish, and real-time monitoring using the Asiatic clam, *Corbicula*. A continuous record of level, temperature, dissolved oxygen (DO), pH, and conductivity was kept from May, 1994, to November, 1995, with the exception of winter months when ice prevented probe deployment and maintenance.

6.2.2 The Kaufman Lake Storm Sewer System

The KLSS system included a storm sewer that discharged into a short channel, which then drained into the main channel of the Copper Slough (Figure 6-2). The storm sewer outlet had a diameter of approximately 1.25 m with continuous flow during dry weather. Although dry weather flow may be due to ground water infiltration, there is also the possibility of flow maintenance by discharge from local industry. Immediately downstream from the sewer outlet, the channel was wide with a well-established pool with a maximum low-flow depth of approximately 1 m. The site is unusual, because the sewer discharge is to a short tributary to the Copper Slough that parallels the reference stream for approximately 50 m. Thus, it was possible to have reference and experimental sites side-by side, facilitating both laboratory testing of collected water samples (see Section 7.3.5) and in situ studies using both WET species (*Ceriodaphnia dubia*, *Hyalella azteca*, and the fathead minnow) and local species (see Section 8.4.1). Further, the storm sewer discharges into the pool produced conditions where sediment accumulates allowing location of in situ sediment toxicity assays (see Section 8.5.1).

At the KLSS, a number of locations were used to monitor receiving water toxicity:

- A reference site on the Copper Slough (CS REF) approximately 50 m above the confluence with the KLSS tributary outlet;

- A second reference site used for one biosurvey;

- A site just downstream (CONFLUENCE) of the point where the discharge channel joins the Copper Slough;

- A main downstream site (DS MID) about 100 m downstream of the confluence with the KLSS basin outlet; and

- Another site further downstream (DS BRIDGE).

Table 6-3 summarizes the toxicity test data and hydrograph information for storm events at the KLSS in 1995 and 1996. In the study, ten storm events were sampled during the period 7/4/95 to 7/21/96 to provide information on seasonal effects on in-pipe toxicity. Table 6-4 summarizes the toxicity data (Microtox, *C. dubia* IQ and lethality tests) obtained for the receiving water samples taken at the KLSS system during an intensive two-week sampling program between 5/20/96 and 6/1/96.

6.3 Trinity River (Fort Worth) Watershed

Four locations were monitored in the Trinity River watershed during a two-week field campaign in May 1995: Sycamore Creek, Cra, Pylon, and Eastern Hills. A field trailer provided by Fort Worth Department of Environmental Management (FWDEM) was located at the Sycamore Creek site and served as a base of operations. The Sycamore Creek site was monitored continuously during the field campaign using both a Datasonde multiprobe and the Mussel Monitor. Two sites (Cra and Pylon) were also continuously monitored with a Datasonde multiprobe. At Eastern Hills, stage height was continuously monitored. Two storm events on 5/2/96 and 5/27/96 were sampled at all sites and tested for toxicity using the Microtox, *C. dubia* IQ and lethality tests. Subsequent events on 7/9/96 and 8/9/96 were sampled by FWDEM at the Cra site and analyzed. Table 6-5 provides a summary of storm events monitored in the Trinity River (Fort Worth) studies.

Figure 6-2. Diagram of Kaufman Lake Sites

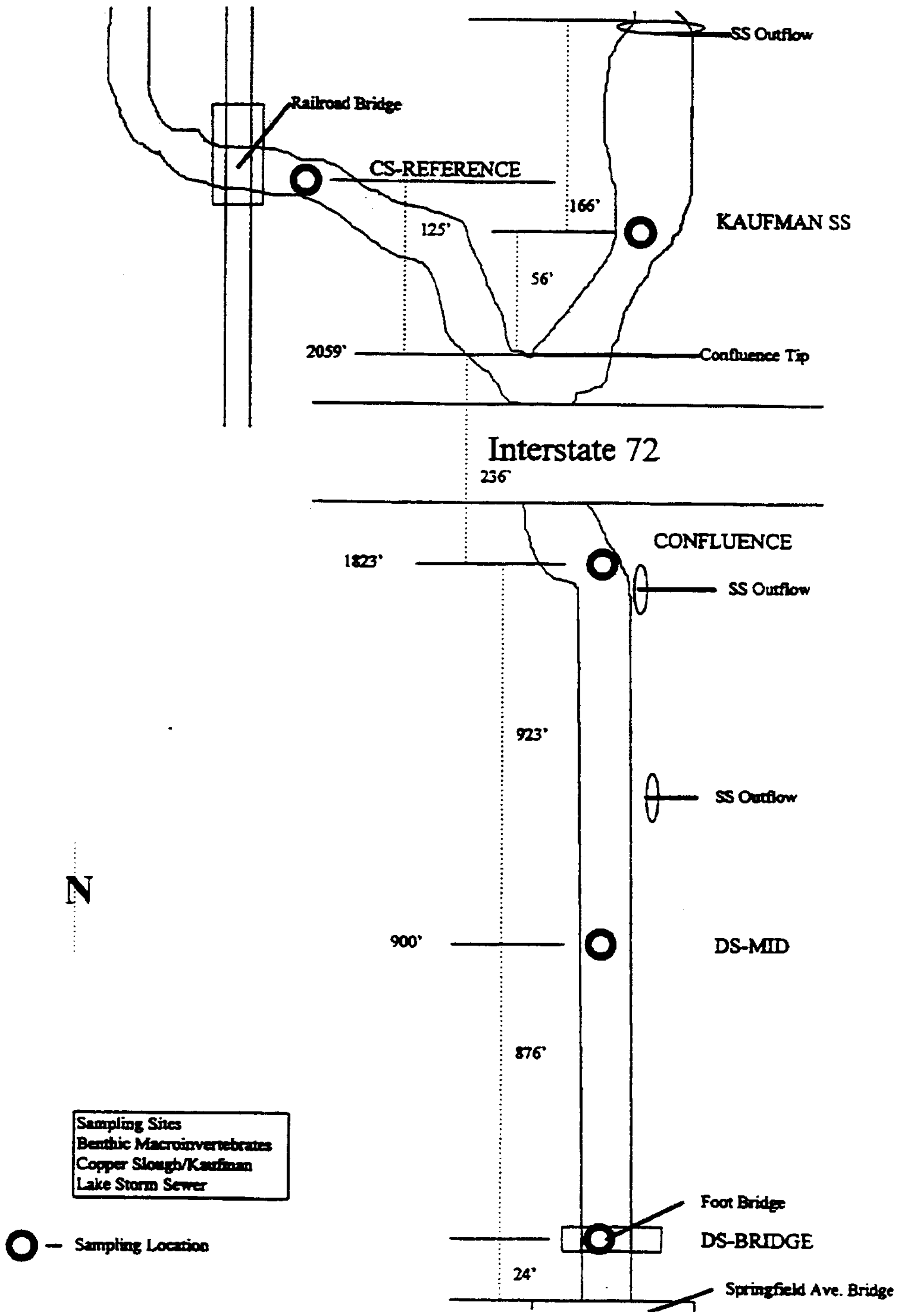


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Table 6-1. Summary of 1994 Storm Events Monitored in the Copper Slough Watershed (US and DS Stations)

Storm date	Hydrograph peak height	Duration of elevated flow (time to 45° slope)	Antecedent conditions (time since previous event)	Conductivity profile (concentrations in mS/cm)	Dissolved oxygen profile	Microtox toxicity test		Rotifer toxicity test		Hyalella toxicity test	
						upstream	downstream	upstream	downstream	upstream	downstream
5/24/94						N	N				
5/30/94	0.65 m	3.5 hrs	6 d	drop 0.7 to 0.5	drop 95% to 60%, <60% for 11 hours	N	N				
6/8/94	0.85 m	5.5 hrs	9 d	drop 0.7 to 0.4	drop 11 mg/l to 9 mg/l	N	N				
6/12/94	-	-	4d	-	-	N	N				
6/19/94	0.90 m	2.5 hrs	11 d	drop 0.7 to 0.3	drop 12 mg/l to <5 mg/l, <5 mg/l for 12hrs	N	N	Y	Y		
6/23/94	0.85 m	3 hrs	4 d	drop 0.7 to 0.3	no observable effect	N	N	Y	N		
7/21/94	0.85 m	5.5 hrs	30 d	drop 0.7 to 0.3	drop 7 mg/l to <5 mg/l, <5 mg/l for 6 hrs	N	-	Y	N		
8/4/94 2 storms	1.25 m	3.5 hrs	18 d	drop 0.7 to 0.3	drop 8 mg/l to around 2 mg/l for 4.5 hrs.	N	-	Y	-		
8/26/94	0.4 m	1.5 hrs	22 d	drop 0.8 to 0.65	increase 12 mg/l to 15 mg/l	-	-	-	-		
8/28/94	0.95 m	4.5 hrs	2 d	drop 0.7 to 0.3	drop 11 mg/l to 3 mg/l, <5 mg/l for 3 hrs	Y	-	N	-	N	-
9/16/94	1.3 m	3.5 hrs	18 d	drop 0.8 to 0.2	drop 7 mg/l to <6 mg/l, but following diurnal trend	Y	Y	N	N	N	-
9/26/94	1.4 m	6 hrs	10 d	drop 0.6 to 0.1	increase 6 mg/l to 8 mg/l	Y	-	N	-	N	-
10/8/94	0.8 m	7 hrs	12 d	drop 0.7 to 0.2	drop 9 mg/l to 7 mg/l <2hrs	N	N	N	N	N	-
10/18/94	0.9m	6 hrs	9 d	drop 0.4 to 0.2	peak curtailed	N	N	N	Y	-	-
11/9/94	1.2 m	24 hrs	3 d	drop 0.5 to 0.16	held low	N	N	-	-	-	-

Y - apparent storm related toxic effect
N - no storm related toxic effect

Table 6-2. Summary of 1995 Storm Events Monitored in the Copper Slough Watershed (US and DS Stations)

Date of Storm	Site Location	Peak Stage Height Increase (m)	Storm Duration (hr)	Time Since Previous Storm Event (days)	Sampling Interval (min)	Microtox Toxicity Test	*C.dubia* IQ Test	*C.dubia* Lethality Test
2/27/95	US	--	6	8	30	N	-	N
	DS	0.16	6	8	30	N	-	N
3/20/95	US	0.18	4	13	30	N	-	N
	DS	0.17	4	13	30	N	-	N
3/22/95	US	0.15	3	3	30	N	-	N
	DS	0.14	3	3	30	N	-	N
7/4/95	US	0.16	3	9	30	N	Y	Y
10/23/95	US	0.21	4	5	30	N	Y	Y

Table 6-3. Summary of the Storm Event Monitored at the Kaufman Lake Storm Sewer (Copper Slough Watershed)

Date and time of storm	Stage height increase (m)	Storm duration (hours)	Antecedent dry period (days)	Pre-storm value	Microtox Samples showing toxicity		Pre-storm values	*C. dubia* IQ Samples showing toxicity		Pre-storm values	*C. dubia* lethality Samples showing toxicity	
					Time (h)	% effect		Time (h)	% effect		Time (h)	% effect
7/4/95 - 11.15	0.1	3.0	9	0	-	-	10	0.53, 0.83	90	0	0.92, 1.17	60
								1.3, 3	80	•	0.75, 1.08, 1.25	50
								1, 1.5, 2.7, 3.2, 3.7	70		0.83	40
								1.2, 2.2, 2.33, 2.5	60		1.0,1.42	30
								1.7, 2	50		2.75	20
								1.8	40			
								2.8	30			
								3.5	20			
7/23/95 - 10.20	0.31	3	19	0	0.7	54.6	10	0.2, 0.25, 0.28, 0.33, 0.37, 0.45	90	0	0.36	60
					0.92	40.2		0.42	70		0.5	50
								0.5, 1.1	60		0.42	40
								0.58, 0.92	50		0.45, 0.7, 0.77, 1.0	20
								0.77, 1	40			
								0.83, 1.2	30			
								0.17, 0.7	20			

Table 6-3, cont. Summary of the Storm Event Monitored at the Kaufman Lake Storm Sewer (Copper Slough Watershed)

Date and time of storm	Stage height increase (m)	Storm duration (hours)	Antecedent dry period (days)	Microtox Pre-storm value	Microtox Samples showing toxicity Time (h)	Microtox Samples showing toxicity % effect	*C. dubia* IQ Pre-storm values	*C. dubia* IQ Samples showing toxicity Time (h)	*C. dubia* IQ Samples showing toxicity % effect	*C. dubia* lethality Pre-storm values	*C. dubia* lethality Samples showing toxicity Time (h)	*C. dubia* lethality Samples showing toxicity % effect
10/23/96 - 19.10	0.2	4	5	-8.1	0.5	25.2	15	1,1.1,1.2, 1.25, 1.33, 1.5, 2	85	0	-	-
					0.67	24.5		1.6, 1.7, 1.8	75			
					0.75	23.4		0.9, 1.4, 1.75, 1.9	55			
2/26/96	0.3	4	>6	-29.4	1.83	57	10	0.38, 1.33	40			
-19.30					1.92	55		0.33, 0.42 0.5, 1.2, 3	30			
					1.67	50		1.25	20			
					2.5	48						
					0.17, 2.1	47						
					1.75	42						
					2.25	36						
					1.58	33						
3/24/96	0.01	5	4	0	0.58	24	10	0.92	50			
- 19.00								0.5, 0.58	40			
								0.67, 0.75	30			
5/23/96	0.2	9	5	0	0.58	87.4	0	1.08	80	0	0.42	50
- 8.30					0.67	64.9		0.92, 1.25	50			
					0.42	43.9		0.58	40			
								1.42, 5.5	30			
								2.0	20			

Table 6-3, cont. Summary of the Storm Event Monitored at the Kaufman Lake Storm Sewer (Copper Slough Watershed)

Date and time of storm	Stage height increase (m)	Storm duration (hours)	Antecedent dry period (days)	Microtox Pre-storm value	Microtox Samples showing toxicity Time (h)	Microtox Samples showing toxicity % effect	*C. dubia* IQ Pre-storm values	*C. dubia* IQ Samples showing toxicity Time (h)	*C. dubia* IQ Samples showing toxicity % effect	*C. dubia* lethality Pre-storm values	*C. dubia* lethality Samples showing toxicity Time (h)	*C. dubia* lethality Samples showing toxicity % effect
6/1/96 - 17.20	2.5	5	4	-0.13	3.5	14	20	-	-	0	-	-
6/23/96 - 2.30												
7/14/96	2.7	8	2	0	0.08	69.6	10	0.08	80	0	0.5	20
- 12.40					0.42	52.2		0.17, 0.33	20			
					0.25	46.8						
					0.17	42.3						
					2.92	23.1						
7/21/96		12	7	0	0.08	48	0	-	-	0	-	-
- 1.25					1.25	28.8						
					1.3	27.8						
					0.25	26						
					0.17	23.9						
					0.33	21.9						
					0.83	21.6						

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Table 6-4. Summary of Toxicity Data for Water Samples Taken from Receiving Water Locations at the Kaufman Lake System

CS Reference								CS Downstream						
Date	Time	Stage ht	Spcond	Microtox % effect	*C.dubia* IQ % effect	*C.dubia* lethality % effect		Date	Time	Stage ht	Spcond	Microtox % effect	*C.dubia* IQ % effect	*C.dubia* lethality % effect
May 20	1800	1.6	0.657	1.5	0	0		May 20	1800	-0.02	0.7	-4.8	20	0
May 21	0	2.2	0.669	-0.07	10	0			2100	0.01	0.7	11.5	0	0
	600	2.6	0.613	2.6	20	0		May 21	300	0.04	0.7	1.6	20	0
May 23	900		0.61	2.6	0	10		May 23	930	3.9	0.63	-0.7	90	0
	1000		0.62	6.4	20	10			1030	3.9	0.61	2	40	0
	1040		0.54	11.4	100	0			1100	3.8	0.61	-5.8	100	0
	1130		0.47	17.5	90	0			1200	3.6	0.59	4	80	0
	1230		0.44	4.4	0	10			1300	3.5	0.6	3	30	0
	1330		0.45	1.7	20	0			1400	3.5	0.62	2	20	0
	1430		0.47	-8.5	20	0			1500	3.4	0.64	-8.4	20	0
May 26	1800	4.7	0.27	25.3	10	20		May 26	2230	0.19	0.47	-14.7	10	0
	2100	4.6	0.35	4.8	0	10			2300	0.19	0.49	28.5	20	10
May 27	200	3.2	0.54	9.7	0	10		May 27	0	0.15	0.53	13.5	10	0
June 1	1330	3.7	0.56	12	20	10		June 1	1330	0.15	0.63	-0.3	0	0
	1700	3.3	0.56	8.6	20	50			1730	0.26	0.63	-6.1	0	0
	1810	5.9	0.24	38.1	10	10			1810	0.49	0.34	14.3	20	10
	1830	5.1	0.16	16.5	0	0			1830	0.39	0.22	9.7	0	0
	1850	4.5	0.17	4.9	10	0			1850	0.31	0.23	10.2	0	0
	2030	4	0.27	-0.74	0	0			1930	0.23	0.27	-6.8	0	0

Table 6-5. Summary of the Storm Event Monitored at Locations on the Trinity River Watershed

Date and time of storm	Stage height increase (m)	Storm duration (h)	Antecedent dry period (days)	Pre-storm values	Microtox Samples showing toxicity		Pre-storm values	*C. dubia* IQ Samples showing toxicity		Pre-storm values	*C. dubia* lethality Samples showing toxicity	
					Time (h)	% effect		Time (h)	% effect		Time (h)	% effect
Cra												
5/24/96 -	0.06	2	>3	0	0.5	46.5	13	0.25-3.75	87	0	1.25-3.25	100
17.15					1.0	31.6		4.25-4.75	77		0.75	63
5/27/96 -	0.07	3	3	0	-	-	10	0.75	90	0	-	-
1.15								4.75	70			
								2.75	50			
								3.75	40			
								3.25	30			
								4.25	20			
7/9/96												
8/9/96												
Eastern Hills												
5/24/96 -	ND	2	>3	4	1.25	36	20	1.25	70	0	-	-
17.15								0.75,1.75	40			
								2.25	30			
								2.75,3.25	20			
5/2/7/96 -	ND	2	3	0	-	-	-	-	-	0	-	-
1.30												
Pylon												
5/24/96 -	0.15	2	>3	0	-	-	20	3.0	30	0	-	-
18.00								0.5,4.5	20			
5/27/96 -	0.1	3	3	0	2.5	25	-	-	-	10	-	-
1.30												
Sycamore												
5/24/96 -	0.12	2	>3	0	-	-	20	1.0,4.0,	70	0	-	-
18.00								4.5				
								2.5	40			
								0.5,1.5	20			
5/27/96	0.22	3	3	0	4.5	100	0	1.5	60	0	-	-
								1.0	50			
								0.5,2.5	30			
								0.08	20			

6.3.1 Cra

The Cra watershed is approximately 47 acres dominated by industrial land use. Runoff through this watershed begins as sheet flow through an open, first-order channel, picking up runoff from bar ditches along a railroad and drainage from a vacant lot composed of industrial landfill. Before reaching the sampling site, the flow picks up drainage from 33rd Street. Industries located within this watershed include Goodyear, Valley Solvents and Chemicals, and several steel foundries and distribution centers. Previous studies have indicated contamination from heavy metals and organics at this location. The sampling site at Cra was located at the mouth of a storm sewer near American Manufacturing, Inc. just south of 33rd Street. The channel downstream from the sampling location was dominated by emergent vegetation (cattail). The channel substrate was sand to fine silt. Depth at the sewer outfall was 12 to 18 in. The Datasonde probe and hose intakes for the Sigma sampler were attached to the bottom of the storm sewer pipe several feet upstream of its opening into the main channel. The Sigma Sampler was positioned on the left overbank of the main channel in a sampling cabinet installed by FWDEM for previous studies. Water quality measurements were made at 15-min intervals, and 500-mL water samples were pumped every 30 min during a storm event.

6.3.2 Eastern Hills

The Eastern Hills watershed is approximately 154 acres and consists primarily of residential areas. Approximately 85% of the watershed is single family residences, while the remaining 15% is multi-family residences. The major sources of possible contamination are residential sewage from overflowing manholes, miscellaneous materials present in streets, and pesticides and herbicides used for lawn maintenance. The sampling site at Eastern Hills was a large storm sewer pipe located near Weiler Boulevard. The Sigma Sampler was secured on top of a drop box inlet with the hose intake positioned just upstream of the inlet. Since a Datasonde probe was not installed at this site, stage readings were recorded by the Sigma sampler instead. A Druck pressure-sensitive probe was connected to the sampler and submerged next to the hose intake to provide stage readings. The stage was recorded every five minutes, and the stage readings were downloaded to a laptop computer at regular intervals throughout the field observation period.

6.3.3 Pylon

The Pylon watershed is approximately 28 acres and encompasses industrial, as well as agricultural, land uses. Various industries, including Graphic Arts, Ravon Industries, and Pepsi Cola Bottling, are located within the watershed. Pollutants carried by runoff include pesticides, heavy metals, and debris from parking lots. The Pylon sampling site was located near the corner of Meacham Boulevard and Pylon Street along a straight channel reach of an unnamed, first-order stream. A Sigma Sampler was installed on the right overbank of the stream. The Datasonde and the Sigma Sampler hose intake were positioned in the middle of the stream about 10 feet upstream of a triangular weir. The stream channel was approximately 15 ft wide with a trapezoidal channel consisting of concrete. Depth at the instrument location was approximately 1 ft. The presence of the weir had resulted in sediment accumulation upstream from the weir. Sediment from this area had been recently removed as a part of regular maintenance activities of FWDEM. Datasonde measurements were recorded every 15 minutes, and 500-mL water samples were collected every 30 minutes during a storm event.

6.3.4 Sycamore Creek

Sycamore Creek receives runoff from a 30,000-acre watershed with mixed land use dominated by commercial and residential areas. The sampling location was approximately 2,500 ft upstream from the confluence with the Trinity River in a fourth- or fifth-order stream channel. The substrate materials varied from sand to large cobble with concrete debris present. The stream channel was approximately 60 ft wide with steep banks of 20 ft. The reach sampled transitioned from a pool through a riffle/run area around a shallow bend. Samples were near the left bank (looking upstream) in a main channel flow. Debris had accumulated in the riparian vegetation indication previous stream depths of 10 to 15 ft. The depth at the sampling location was approximately 2 ft.

6.4 Cuyahoga River (Cleveland) Watershed

Mill Creek is a tributary of the Cuyahoga River (at River Mile 11.3), flowing east and then south approximately 14.5 km through a completely urbanized watershed including all or part of the following communities: Beachwood, Bedford Heights, Cleveland, Garfield Heights, Highlands Hills, Maple Heights, North Randall, Orange, Shaker Heights, Solon, and Warrensville Heights. The drainage area is approximately 11,600 acres with unmodified channel conditions for most of its length. In general, sampling stations extended from an upstream area affected mainly by residential discharges through midstream stations subject to industrial and CSO influence to a downstream station near the Cuyahoga River.

Sampling in Mill Creek was conducted by the Northeast Ohio Regional Sewer District, and samples were sent to the University of Illinois for laboratory analysis. Stormwater samples were collected from four sites on Mill Creek during the 7/15/95 storm event. These samples were tested for toxicity using Microtox, *C. dubia* IQ and lethality tests. These analyses were part of a larger study assessing the impact of storm discharges at 11 sites in the Mill Creek watershed. As part of the larger studies, chemical analyses, toxicological testing, and benthic surveys were completed in 1995. Reporting on the Mill Creek Watershed Project is available from the Northeast Ohio Regional Sewer District in a report published in August, 1996.

CHAPTER 7.0

LABORATORY-BASED STORM EVENT ANALYSIS

7.1 Introduction

This chapter, and Chapter 8.0, raise questions that users should ask when designing their wet weather event assessment programs and provide relevant information and answers using information generated in this research. This chapter covers issues relating to laboratory-based analyses, while Chapter 8.0 deals with field-based analyses.

These two chapters are not intended to provide exhaustive answers to all the questions the designer of a wet weather analysis program might ask. That would be impossible due to the site-specific and objective-specific nature of any program. What is intended is that these questions will prompt users to ask the right kinds of questions that will lead them to an appropriate design, and the answers will provide guidance on the issues to address.

7.2 Where Do I Start?

Since it can be difficult and expensive to obtain conclusive data on the effects of wet weather events, it is vital that assessment programs are carefully designed to meet specified objectives and also to be cost effective. Two types of objectives must be defined at the outset of the program:

- **General** objectives describing program goals; and
- **Specific** objectives relating directly to the measurements necessary to meet general program objectives.

Assessment programs frequently fail to meet defined objectives even when carried out as specified, because the sample size is insufficient to confirm or reject study hypotheses in a statistically acceptable manner. This problem stems mainly from the high variability in runoff and natural aquatic systems. Sources of variability include spatial differences in parameters in a waterbody, differences in parameters at a location over time (temporal variability), and errors in the measurements of parameters. All these potential problems can be addressed by ensuring at the beginning of the study that the number of samples (location, time, and replicates) taken are sufficient to meet study objectives considering variability and cost constraints. Chapter 3.0 covers elements of wet weather assessment program design, and further detailed information on monitoring program design can be obtained from Mar et al. (1986); Reinelt, Horner, and Mar (1988); Reinelt, Horner, and Castensson (1992); and Horner et al. (1994). See also Sections 7.5.1 and 7.5.4.

Horner et al. (1994) described a procedure for estimating the cost of programs using the formula:

$$TC = C_o + (T \times C_T) + (S \times T \times C_s) + C_r\ (R \times S \times T) \tag{7.2-1}$$

where: TC = Total cost;

- C_o = Fixed overhead cost;
- C_T = Fixed cost for each sampling occasion;
- C_s = Cost associated with visiting each sampling station;
- C_r = Cost to collect and analyze each sample;
- T = Number of sampling occasions;
- S = Number of sampling stations;
- R = Number of replicates on each occasion at each station.

The function R x S x T = the total number of samples, and, for a given budget, the three quantities can be varied so long as the total remains the same. For example, if measurement error is larger than natural variation, then adding replicates would reduce uncertainty more than adding stations or occasions. However, if spatial or temporal variation are most important, adding stations or occasions respectively would be a better strategy.

7.3 Analysis Design Questions

7.3.1 Where Do I Sample?

The locations sampled within a watershed depend on the objectives of the assessment program and wet weather event characteristics. The protocol (see Chapter 3.0) defines three objective-related sampling locations:

- **In-pipe**, where the objective of the study is analysis of a defined drainage area or assessment of the performance of control facilities or assessment of a specific source. Samples should be taken either in the pipe during the discharge or, if this is not possible, at a near-discharge location that provides minimum mixing with the receiving water. The dilution and dispersion available in the receiving water needs to be considered before any conclusions can be drawn on the potential environmental impact.

- **Receiving waters (single discharge)**, where the objective of the study is the assessment of the impact of a single discharge. The locations selected should provide a reference (see Section 7.3.4) sample and a well-mixed discharge/receiving water sample that identifies the effect of the discharge as modified by the receiving water.

- **Receiving waters (multiple discharges)**, where the objective of the study is:
  a) establishing reference conditions for a location in a watershed;
  b) assessing the effects of multiple, or diffuse source, discharge effects at a site or sites;
  c) long-term surveillance of dynamic (wet weather)/static (baseline) receiving water condition

The locations selected should be based on discharge locations and receiving water characteristics and may require consideration of temporal (seasonal, see Section 7.3.3), as well as spatial effects. See also Section 7.5.1.

7.3.2 What Do I Sample?

The sampling program adopted again depends on the objective of the study and includes assessment of both water column and sediment toxicity. In the first instance, a series of water samples should normally be taken from appropriate locations and tested using basic screening tests (see Section 7.4.2) to assess the level of toxicity (toxicity classification, see Section 3.4.3). The frequency of sampling required and the nature of the samples taken (grab or composite) depends on the characteristics of the system under study and the precision called for by the study objectives.

However, over time, runoff pollutants, such as metals, accumulate in the sediment rather than the water column. Therefore, assessing cumulative effects of watershed runoff and nonpoint sources on aquatic systems should include evaluation of sediments and the toxicity to indigenous organisms. Alternative assessment methods are needed to determine the actual environmental effects of runoff.

7.3.3 When Do I Sample?

Since wet weather events do not occur at evenly spaced intervals, it is not appropriate to adopt set monitoring intervals (such as weekly or monthly) but to target sampling to site-specific characteristics in terms of the input and the receiving water characteristics. The results of hydrologic analyses at a site should be used to support sampling programs. For example, information on seasonal occurrence of storms, typical magnitude, duration, and inter-storm periods can all be useful in targeting sampling to maximize the chances of capturing storm event data at minimal cost (see Section 2.3). Information was used in this way to target the sampling program undertaken in this project at Fort Worth. Seasonal storm frequency information was used to select the sampling period at the Fort Worth sites which would have the highest probability of providing storm events (see Section 6.3). Further information on typical intervals between storms was used to predict the number of storms which might be expected within a sampling program of a given duration (for example, see Table 2-1).

In addition to targeting the general sampling period to maximize capture of useful data, one must consider when to sample in relation to organism exposure to contaminants. The protocol (Chapter 3.0) defines three sampling frequencies that are designed to meet specific objectives:

- Intra-event;
- Event; and
- Multiple event.

7.3.4 What Constitutes a Reference Sample?

A reference sample is one that is used to compare with those taken during a storm event. When monitoring in-pipe toxicity, a reference sample can be:

- One or more samples taken before the storm event (that is under dry weather flow); or
- A laboratory control, if there is no dry weather flow.

When monitoring the impact of single or multiple discharges to receiving water, two different types of reference sample can be identified, serving different purposes:

A **local or upstream reference sample** is one that is used for direct comparison with an impacted site to infer the effect of a single discharge, multiple discharges, or runoff zone. Typically, these samples are taken at a site upstream of the impacting discharge or impacted area. The results from samples taken at this site are compared with results from the downstream, impacted site. For example, at the KLSS system, an upstream reference was located about 50 m upstream of the confluence with the KLSS basin (see Section 6.2).

Although an upstream reference site allows the identification of the impact of a particular input, it does not allow an identification of the impact of other input sources or a general degradation in water quality. Collecting a sample from general or background reference sites might aid is making such a distinction.

A **general or background reference** sample is taken from a site that is free of (major) anthropogenic influence and provides a measure of natural background conditions. By comparing the results of tests on samples taken from a general reference site, an upstream reference site and an impacted site, it might be possible to infer the relative importance of the impact of the input under study in relation to that caused by other inputs. A reference site can be situated in the upper reaches of the watershed, above known inputs, or on a different, unimpacted stream. If samples are taken from different systems, then it is vital to ensure that results of toxicity tests are not influenced by differences in physicochemical factors, such as water hardness and pH. See Section 7.5.1 for more detail on this issue.

7.3.5 How Can Toxicity Change Through a Storm Event?

Within an event, the toxicity measured at different times depends on the concentration of substances present in the runoff and their bioavailability to test organisms. The concentrations of substances present, and, hence, the resulting toxicity, are almost infinitely variable depending on rainfall intensity, the length of the antecedent dry period, deposition on urban surfaces or application of chemicals (such as pesticides and herbicides) on farm or residential land during the antecedent period and surface characteristics.

In a storm event, the first flush of runoff typically contains relatively high concentrations of contaminants which may then fall markedly and fluctuate at lower levels for the remainder of the wet weather event. As a result of this contaminant concentration pattern through an event, the highest levels of toxicity would be expected to generally be associated with this first flush. However, the first flush sometimes is not apparent, or is less pronounced, when rainfall is not intense or follows soon after an earlier storm that has removed the majority of the available contaminants. A secondary peak in contaminant concentrations (and toxicity) can appear if a sudden burst of intense rain during the event drives material off surfaces not completely cleaned by the initial runoff (Horner et al., 1994).

Figure 7-1 shows when peak toxicity values in the Microtox, *C. dubia* IQ and lethality tests were measured after the start of storms at the KLSS. Peak toxicity was usually observed with both the Microtox and *C. dubia* IQ tests between 5 and 60 min after the start of storm water runoff at the sewer.

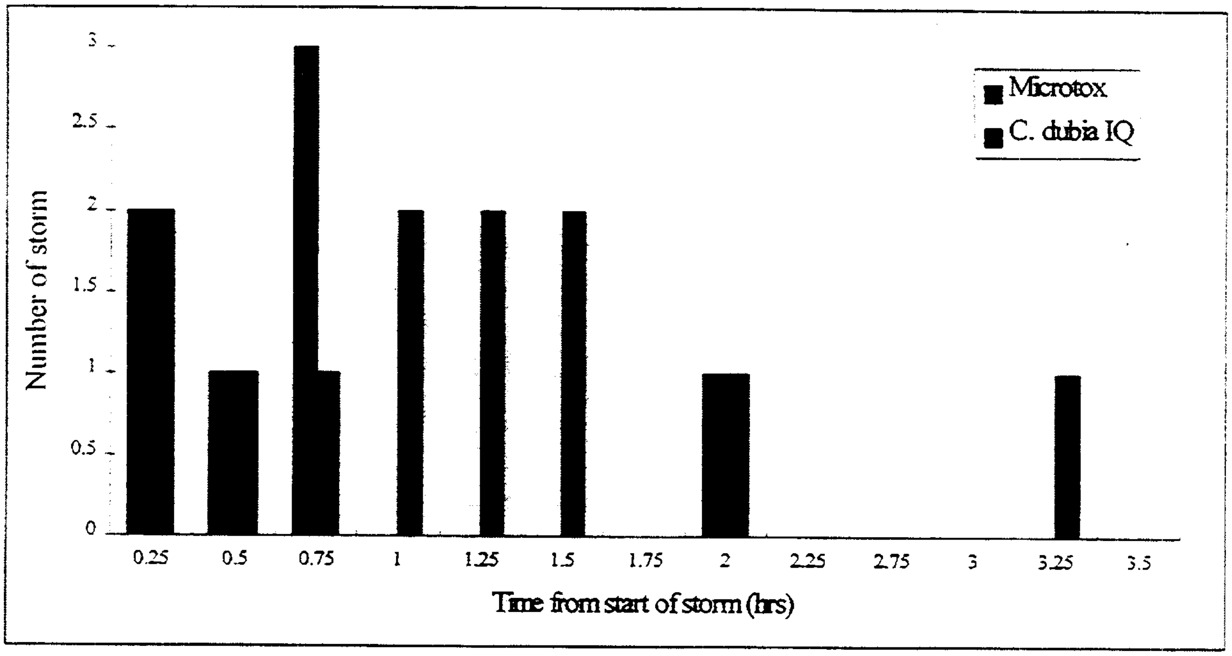

Figure 7-1. Times from Start of Storms to Observation of Peak Toxicity as Measured by the Microtox and *C. dubia* IQ Tests

An example of the pattern of toxicity measured at the Kaufman Lake storm sewer during an event is shown in Figure 7-2. The 7/14/95 storm event started at 12:40 and the highest toxicity values in basic screening tests (Microtox and *C. dubia* IQ) were measured at 12:45. After 30 minutes, responses in both tests had fallen to pre-storm values. These data are consistent with studies carried out with stormwater samples from various Los Angeles River locations with the Microtox test (Raco, 1988). See also Section 7.4.6.

To identify toxicity related to a first-flush effect or toxicity related to another specific period of an event, sufficient sampling will give an adequate profile of effects through the event. This will inevitably require event-triggered sampling with an auto-sampler. The sampling frequency sampling depends on the characteristics of the system and the precision called for by study objectives.

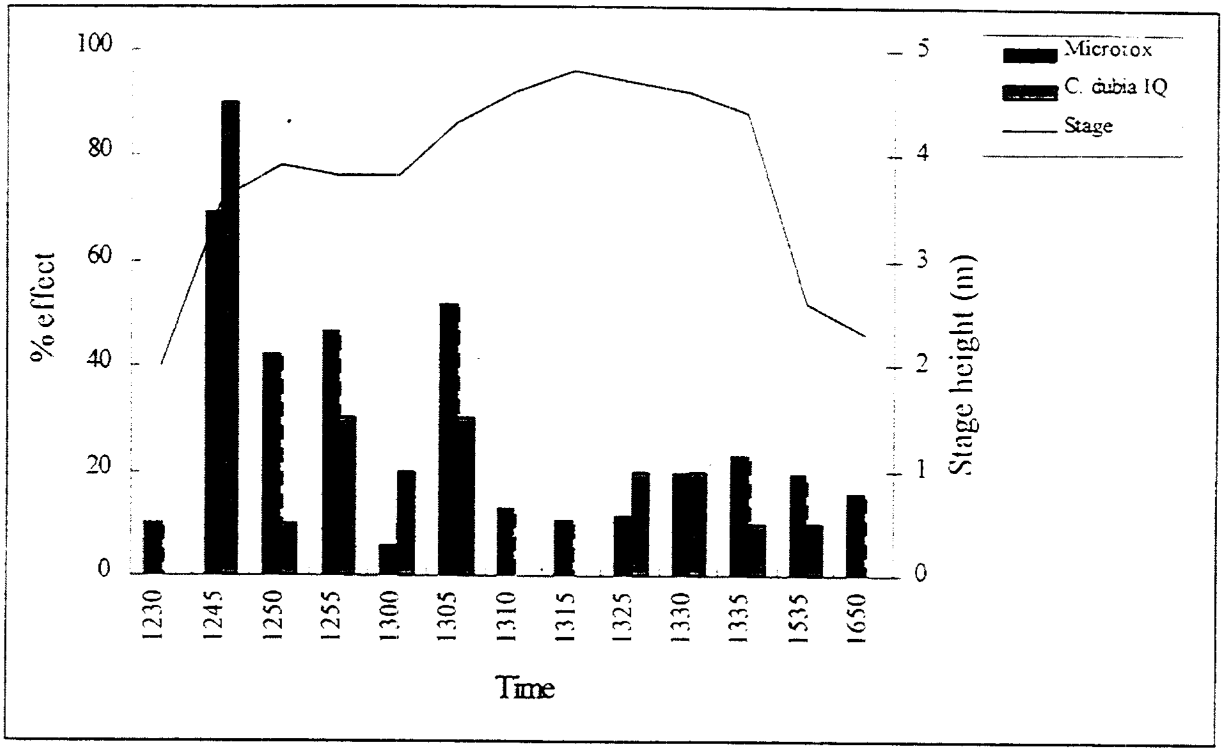

Figure 7-2. Toxicity Data for the 7/14/95 Storm at KLSS

7.3.6 How Do I Design a Sampling Program to Identify/Separate Water Column/Sediment Effects?

The sampling program to identify/separate water column/sediment effects must reflect the time scale of exposure of receiving water organisms.

Acute toxic responses of receiving water column biota to wet weather events are associated with a transient change in the concentration contaminants that can last for only a short time, although post-exposure effects may occur. The extent of these toxic responses in the receiving water depends on the magnitude of stormwater runoff relative to receiving water volume and the extent of dilution. Where dilution is high, contaminant concentrations in the receiving water might not be high enough to directly or rapidly affect aquatic organisms. However, continued runoff with relatively low contaminant levels can eventually cause toxic responses in two ways:

- Cumulative water column stress resulting in chronic effects; or
- Pollutant accumulation in aquatic sediments resulting in effects on epibenthic and benthic organisms.

The sampling program must accommodate the need for separate sampling and testing of water and sediments, as well as combined use of in situ tests and bioassessment programs. The event toxicity unit (ETU) metric developed as an indicator of time-scale toxicity can be used to identify water column effects (see Section 5.2.3). Although identified as an area for further research, this project has developed evidence that suspended solids, possibly resuspended sediment, can contribute to toxicity during a storm event. For this reason, a complete definition of water column toxicity might require separate testing for soluble and solids components of storm samples. In addition, full site toxicity characterization may require sediment toxicity testing, either laboratory- or field-based.

7.4 Test System Questions

7.4.1 What is the Best Test System for Toxicity Analysis?

In assessing the impact of wet weather events, time-scale considerations are the basis for the selection of appropriate toxicity assessment procedures. In the protocol described in Chapter 3.0 to support the assessment of both short-term and long-term changes in receiving water condition or quality, three time-scale divisions (intra-event, event, and long-term) are identified. These divisions recognize that effect identification, test system selection, and actual measurement of effect, analysis and interpretation of consequence must all meet criteria that are specific to an identified time scale. If toxicity is the indicator, then in short-term exposures (intra-event time scale) where concentration transients are very large (orders of magnitude), responses need to match the time scales of exposure found during the storm. When analyzing whole events, particularly as modified by BMP operation, the time-scale analysis selected (event time scale) should reflect the fact that BMP effluents have some characteristics of the storm event (for example episodic nature with variable volume and concentrations associated with the effluent). However, BMP effluents typically vary less with longer, but constant effluent flow times.

As a matter of convenience, event time scales are measured in two categories; Category #1 would be appropriate for short duration convective storms for which event duration is measured in hours, and Category #2 where event duration requires multiple composite samples or BMP presence extends a storm's influence so that an event duration is measured in days. Finally, toxicity analysis related to extended contaminant residence or accumulation of contaminants requires tests appropriate for a long-term time scale, where exposure durations are very long (days to months).

The protocol also recognizes that a tier testing approach is essential to a logical and cost-effective analysis of wet weather discharges that are highly variable. Following an extensive evaluation of test systems, assays, and sampling approaches, the tier testing scheme proposed for wet weather discharge analysis emphasizes basic and advanced testing in a screening tier followed by confirmatory testing, which verifies the predictions of the screening tier where required. The use of a structured tier testing approach allows the required level of information needed to be obtained in a cost-effective manner (see Section 3.4).

Since different test systems are based upon different responses to toxicants, one test cannot be relied upon to respond to all wet weather events. Consequently, an optimized test battery is needed to minimize incidences of false negatives in detecting the toxicity associated with events of different duration. The need for a test battery for each time-scale division is consistent with the consensus view of regulators involved in controlling point source discharges (US EPA, 1991; Environment Agency, 1996).

7.4.2 What is a Basic Screening Test and When Should I Use One?

A basic screening test is a simple, easy-to-use, cost-effective test that measures effects observed in an undiluted sample over a period typical of the storm event(s). Basic screening tests are intended to *illuminate* the problem and supply sufficient information to identify toxicity and classify toxicity as nonexistent, moderate, or high. See Section 3.4 for more information on basic screening tests and their application. An example of test system identification for basic screening tests is provided in Section 4.6.

7.4.3 What is an Advanced Screening Test and When Should I Use One?

An advanced screening test provides a measure of effects observed in a series of a sample dilutions over a period typical of the storm event(s). Advanced screening tests are intended to lead to more focused analysis to identify toxicant type, contaminant source, mechanisms of toxicity, or toxic effect (see Section 3.4). These tests are selected to identify sources of contamination, better characterize individual storm events for later comparison or classification, or identify toxic effects that can be used to direct confirmatory testing to appropriate targets.

7.4.4 What is a Confirmatory Test and When Do I Use One?

A confirmatory test is a laboratory- or field-based procedure to verify effects predicted from earlier basic and advanced screening tiers (see Section 3.4). If high or moderate toxicity is revealed by screening tests, confirmatory tier tests may be used to confirm that there is an impact on the receiving water ecosystem (see Appendix C). Confirmatory testing can be integrated with monitoring efforts that are designed to identify unanticipated long-term or low-level effects.

7.4.5 What are the Characteristics of an Optimal Test Battery for Storm Event Analysis?

The optimum test battery for assessing intra-event, event, or long-term toxicity must be cost-effective, minimize false negatives and false positives, but should not incorporate unnecessary redundancy (that is, tests showing similar responses). Careful consideration of the test battery is required to achieve this balance. Too few tests increases the risk of false negatives (i.e., test not responsive to a particular contaminant), as well as that of false positives (i.e., rogue results from a single test). Results must be interpreted with care (Section 7.9.4). Identifying appropriate test batteries for each time-scale division has been a key element of the project, and the selection procedure used is described in Chapter 4.0.

7.4.6 What is the Optimum Screening Test Battery for Analyzing Intra-Event Toxicity?

For intra-event analysis, toxicity tests performed with grab samples must involve exposure durations that range from minutes to a few hours. A possible test battery, used in this project, includes the acute Microtox procedure, the *C. dubia* and *H. azteca* IQ test, and modified time-scale-specific versions of WET tests using *C. dubia* and *H. azteca*. (see Chapter 5.0 for details of the development and application of these procedures).

Table 7-1 summarizes the results of toxicity tests with the Microtox and *C. dubia* IQ tests on intra-event samples from a series of storms at the Kaufman Lake and Cra (Fort Worth) storm sewers. The data have been analyzed for correlations between the two tests and to ascertain whether each test indicates toxicity during a particular storm event.

The data in Table 7-1 indicate that the Microtox and *C. dubia* IQ tests showed toxicity in the same storm event, but the responses for all samples taken during the event do not correlate closely; the two tests indicate peak toxicity at different times of the storm hydrograph. On this basis, the two tests represent a useful screening battery since both would confirm whether or not there is toxicity in a storm event, but the two tests provide complementary information in terms of when peak toxicity occurred during an event.

Time-scale lethality tests using *C. dubia* and *H. azteca* (in which organisms are exposed to storm water samples for periods of 15 to 240 minutes followed by up to 6 days in clean water) are also considered a component of the basic screening test battery for intra-event analysis. The *C. dubia* time-scale test was used to test samples from the 5/24/95 storm at the Cra storm sewer taken at 6:30 p.m., 7:30, and 9:00. These samples had previously shown a range of responses to the Microtox (47%, 32%, and 3.4% light inhibition respectively) and the *C. dubia* IQ test (90%, 80%, and 80% inhibition of fluorescence). The PE-LET_{50} values of 64.3, 130, and 1,188 min for the 6:30 p.m., 7:30, and 9:00 samples were consistent with the patterns of response for both the Microtox and, to a lesser extent, the *C. dubia* IQ test. Overall, the storm event showed an ETU of 1.05 indicating that this event would cause approximately 50% lethality to *C. dubia* (see Section 5.2.2).

The Microtox test system has been used previously by Raco (1988) to measure responses in storm water runoff samples collected from storm channels at three locations on the Los Angeles River, the San Gabriel River, and Ballona Creek in Los Angeles County. The maximum levels of response measured (as % light inhibition) in storm sewers within Los Angeles County were 16% to 67% (see Table 7-2).

The Microtox test has also been used extensively in a screening role in projects carried out under the US EPA Storm and Combined Sewer Program (for example see Pitt et al., 1990).

7.4.7 What is the Optimal Screening Test Battery for Analyzing Event Toxicity?

For event analysis, the tests used need to have exposure durations consistent with typical site-specific event duration. Depending on event duration, test systems selected for the test battery can be divided into two categories: 1) response induction, observation, and measurement time < 24 hours, or 2) response induction, observation, and measurement time of 24 hours or greater. Category #1 would be appropriate for short-duration convective storms and would include test systems that are also appropriate for intra-event analysis. Category #2 would be appropriate for event composite samples, BMP assessments, particularly when detention facilities are in use. An optimal test battery for Category #2 include comprise standard WET procedures using *C. dubia* and *H. azteca*.

7.4.8 When Do I Need to Conduct Sediment Toxicity Testing?

Sediment toxicity testing might be needed for stormwater discharges that are releasing large amounts of suspended material to receiving water environments. In these discharges, many toxicants might bind to the particulate matter, and any resultant in-stream impacts might not be evident in the water column but rather in the sediment when this material is deposited. These tests can also be used in studies where the objective is to determine whether receiving water impacts are due solely or in part to the resuspension of material during a storm event.

7.5 **Sampling Questions**

7.5.1 When and Where Should I Sample to Determine Intra-Event, Event, and/or Long-Term Toxicity in a Watershed?

The frequency of sampling and the location of sampling stations for intra-event, event, and/or long-term toxicity testing in a watershed must be carefully defined to ensure that study objectives are met while considering variability and cost constraints. Information on when to sample intra-event, event, and long-term toxicity is summarized in Table 7-3. In the cases described in the table, except for intra-event programs targeted solely at in-pipe sampling, sampling should be conducted at locations upstream and downstream of the input. Downstream sites need to take account of the physical mixing zones of inputs. A site within the immediate mixing zone might be required to examine maximum impact, but for the assessment of the wider downstream impact, sites should be outside the immediate mixing zone. Selecting a reference location can be problematic in many studies, because entire watersheds may be highly modified by urbanization or other changes from natural land uses. Readers are referred to US EPA discussions on reference areas (US EPA, 1996) and the discussions in Section 2.6.

7.5.2 How Long Can I Store a Sample?

Any toxicity analysis of water samples should be carried out as soon as possible. General guidelines state that the maximum storage time should not exceed 24 hours. However, it should be noted that sample toxicity can decrease markedly in less time, highlighting the need to test as soon as possible. Stored samples should be refrigerated.

Table 7-1. Comparative Data for the Microtox and *C. dubia* IQ Tests for Stormwater Samples

Location	Date of storm	Microtox data			*C. dubia* IQ data			Correlation between Microtox and *C. dubia* IQ (r)
		Toxicity measured?	Maximum response (%)	Time from start of storm (h)	Toxicity measured?	Maximum response (%)	Time from start of storm (h)	
Kaufman Lake	6/1/96	No	13.8	3.17	No	10	0.17	0.15
	7/14/96	Yes	59.4	0.08	Yes	90	0.08	0.67
Cra	7/9/96	Yes	76.4	0.1	No	22	0.18/0.85	0.33
	8/9/96	Yes	81.3	-	Yes	100	-	0.33

Table 7-2. Microtox Responses Measured in Undiluted Stormwater Samples Taken at Various Los Angeles River Locations (after Raco, 1988)

Location	Date of storm	Range of Microtox responses (% light inhibition) during storm	Maximum Microtox response (% light inhibition) during storm
Los Angeles River	1/4/87	13-36	36
	3/21/87	33-67	67*
	10/22/87	6-13	13*
	12/4/87	10-16	16
San Gabriel River	1/4/87	15-22	22
Ballona Creek	1/4/87	29-40	40*

* Might be an underestimate of potential response as samples were not taken during the first peak of flow

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Table 7-3. Factors for Determining Time Scale of Toxicity Testing

Intra-event	Event-triggered samples are required, taking discrete samples through a storm event. Precise timing and sample frequency depend on the resolution required by the program objective.
Event	Flow proportional composite samples are taken by automatic samplers at each location. Sampling should encompass pre-storm conditions and the entire storm (as defined by hydrologic or water quality analysis), which might require collection over 24 hours or longer. The duration of the sampling is determined by the hydrograph in the receiving system.
Long-term	For the analysis of long-term toxicity, the sampling program depends on the study objectives and complexity of the system under consideration. Discrete sampling can be used, but periodic composite sampling is the mainstay of long-term toxicity monitoring. In situ and biosurvey monitoring techniques should also be used (see Chapter 8.0). Where events are widely spaced in time, each storm is treated as a single entity and a picture of multiple event toxicity is built up from single events. If multiple event toxicity is being determined, it might be necessary to sample receiving water between storms to build up a profile of changes in dry weather flow toxicity. Sample collection procedures should adequately address natural variability, identify single event effects with certainty, and support separation of event effects from other influences on receiving water quality. If events follow each other more closely, then the sampling regime can be extended to encompass all the events. Discrete sampling can be used, but periodic composite samples should be relied upon mainly. Sediment and water column toxicity should measured during the program. In situ monitoring techniques should also be used (see Chapter 8.0). The frequency with which storm events are sampled over time should reflect the pattern of events at a particular location (see Section 2.3).

In the course of the testing program, a series of storm water samples were tested after varying periods from the time of collection. Only stormwater samples showing toxicity in the original tests were selected for re-testing. Table 7-4 summarizes which samples were re-tested using the *Ceriodaphnia* IQ and lethality tests and the length of time between re-testing.

Table 7-4. Summary of the Repeat Tests on Stormwater Samples Using Basic Screening Tests

Location	Date of storm	Tests carried out	Time between tests (days)
Cra (Ft Worth)	5/24/95	*C. dubia* IQ and lethality tests	29
Cleveland	6/17/95	"	14
Kaufman Lake (Champaign)	7/4/95	"	7

Statistical analysis of the original and repeated tests assessed whether the differences in responses on the two occasions were significantly different from zero (paired t-tests). Table 7-5 shows the results of these analyses and indicates that for *C. dubia* IQ tests changes in toxicity were not related to the original level of toxicity or the time between tests. For the *C. dubia* lethality tests, changes in toxicity appeared to be related to the initial level of toxicity. However, overall the data indicate that it is difficult to predict what effect the storage of samples will have on their toxicity. Changes in toxicity are likely to be dependent on the types of contaminant present, and whether these are conservative or non-conservative.

Table 7-5. Summary of Statistical Analyses of Repeated Tests on Stormwater Samples

Location	Time between tests (days)	Significance of comparisons of tests	
		C. dubia IQ	*C. dubia* immobilization
Cra (Ft Worth)	29	NS	P<0.05
Cleveland	14	P<0.05	NS
Kaufman Lake (Champaign)	7	P<0.05	P<0.05

For the chemical analysis of samples, maximum acceptable storage times vary for different determinands, depending on their stability or how effectively they can be preserved. Guidelines for the storage of samples for chemical analysis should be consulted.

Sediments should ideally be tested as soon as possible after collection but can be stored refrigerated for up to 14 days before testing (ASTM, 1996).

7.5.3 How Much Sample Should I Collect?

The amount of sample required will depend on the analyses (toxicity testing and chemical analyses) to be performed on it. In determining the volume of sample needed it is important to allow some contingency and when using automatic samplers to remember that the capacity of the machine will limit the maximum volume of any one sample. Table 7-6 shows the amount of sample required for different types of toxicity and chemical analyses.

Table 7-6. Volume of Sample Required for Different Types of Toxicity and Chemical Analysis

Type of analysis	Volume of sample required (ml)	
Toxicity tests	Screening	EC_{50}
Microtox	4	5
C. dubia IQ	80	155
C. dubia lethality	80	155
C. dubia time scale	100	194
H. azteca lethality	200	388
H. azteca time scale	1,000	1,940
Chemical analysis		
Ammonia	100	
Metals (Total)	100	
Metals (Dissolved)	100	
Pesticides	2000–4000	
PAHs	2000–4000	
TSS	250	

7.5.4 What Should I Expect Sampling and Analysis to Cost?

Analytical costs vary according to the type of test and the number of samples that can be processed at one time. Typical analysis costs for metals range from approximately $10 to $20 per metal per sample. A simple pesticide scan can range from $250 to $400 for organochlorine, and organophosphate, pesticides, and chlorinated herbicides. Many laboratories have custom analysis sets for pesticides commonly used in the area, and analytical costs can be reduced by selection of specific pesticides or pesticide groups. Typical polycyclic aromatic hydrocarbon (PAH) analysis varies from $250 to $350 per sample. Total organic carbon (TOC) costs range from $40 to $60 per sample; chemical oxygen demand (COD) is approximately $20 to $30 per sample; ammonia nitrogen $15 to $25 per sample and pH, total suspended solids (TSS), conductivity, hardness, etc. typically costs from $5 to $25 per analyte per sample.

7.5.5 Where Should I Sample in a Sewer System, in Relation to an Outfall, or in a Drainage Network?

The selection of sampling locations in a sewer system is based on the objectives of the study. A common objective is to determine the source of identified toxicity, but that objective should recognize that toxicity might originate from a range of sources in a sewer system, even rainwater (see Section 7.6.5). A first level analysis identifies "watersheds" in a sewer network and sample at nodes in that network. For example, a typical sewer system has smaller diameter pipes as primary collectors, then progressively larger pipes to carry greater expected volumes. Sampling locations to define watershed input can be easily identified by pipe diameter changes in a network. If the objective is source identification, then sampling points should be selected upstream and downstream from a suspected source. To address the rainfall "background" toxicity, parallel testing of rainwater might be required.

There are numerous "special" sampling issues that should be considered in sewer system sampling. For example, if an outfall is to a receiving system that has different water surface elevations (e.g., a tidal system, or a detention facility that might surcharge), then sampling in the pipe should be at a location where backwater effects are not observed.

7.5.6 When and How Should I Collect Composite Samples?

Composite samples should be used if the focus of the analysis is on the event time scale, particularly if the study involves a detention facility, which tends to average the quality of a discharge over time. In intra-event analysis, the event duration, particularly single storms that last several days, can dictate that consecutive time-sequenced composite samples be collected. Compositing is intended to provide a sample representative of average toxicity over a given time. The most reliable compositing method is a flow-weighted composite, where samples are triggered based on flow volume passing a sampling point. If the flow conditions are expected to be constant, a time-weighted composite can be collected.

The compositing interval must be selected with care so that is consistent with the event being evaluated and so that recommended sample holding/storage times are not exceeded. For example, a long duration storm, which produces a multiple day hydrograph, requires interval composite sampling where more than one flow-weighted composite sample is required, usually defined based on a fixed time interval associated with analysis criteria. Some events, particularly in the Pacific Northwest can be of low intensity and long duration. Again, special compositing techniques can be required that incoťporate either flow-weighted or time-sequenced sampling to produce an accurate storm composite.

As part of time-sequenced storm event sampling, various post-sampling composites were made to assess the effects of compositing samples on toxic response in *C. dubia* (assessing both toxicity and IQ enzyme response) and Microtox. Sampling of the storm event began at 19:10 on February 26, 1996, and was initially set for 30-min intervals. With the onset of the storm, the sampling interval was approximately 2.5 minutes. A second event was sampled from 20:40 at five-min intervals. Composites were made of the entire sampling sequence, compositing equal volumes from samples collected at 30-min intervals. A second composite was made of the early storm event with equal volumes composited from samples collected at 2.5-min intervals. A third composite was made of the late storm event with equal volumes composited from samples collected at 5-min intervals. The results of toxicity testing on the discrete samples are shown in Table 7-7, together with the build-up of the composite samples.

Table 7-8 shows the results of toxicity analyses of the composite samples. In the total event composite (#1), individual samples ranged from 0% to 100% toxicity to *C. dubia* while the composite produced 40% toxicity. *C. dubia* IQ results ranged from 0% to 100% effect, with all samples after 19:44 producing 100% effect. The composite sample also produced 100%. Microtox results were variable, with initial samples in the sample sequence, along with samples collected after 21:05, inhibiting light output. The composite sample produced no response in the Microtox assay. For other composites, when *C. dubia* toxicity (as inhibition of IQ response or lethality) was observed in individual samples, the composites produced no toxicity (<20% effect criterion). The results for the Microtox assay indicated toxicity in composite #2 where only stimulation was observed in individual samples. This result appears to be anomalous. The Microtox result for composite #3 was considered nontoxic (<20% effect), while four of the individual samples had a toxic response of 20% or greater.

Table 7-7. Toxicity Analyses of Discrete Samples and Build-Up of Composite Samples

Sample time	Build-up of composites		*C. dubia* lethality (% effect)	*C. dubia* IQ (% effect)	Microtox (% effect)
19:10	1		10	0	24.64
19:40	1		100	20	17.51
19:44		2	0	80	-45.29
19:47.5		2	0	100	-23.71
19:50		2	0	100	-15.75
19:52.5		2	0	100	-13.57
19:55		2	20	100	-15.40
19:57.5		2			-22.23
20:00		2	0	100	-24.89
20:12.5	1				
20:40	1	3	0	100	-16.3
20:45		3	70	100	-18.39
20:50		3	0	100	-22.42
21:00		3	0	100	-11.67
21:05		3			3.54
21:10	1	3			20.25
21:15		3	40	100	11.84
21:20		3			27.34
21:25		3			25.12
21:45	1		0	100	6.62

Table 7-8. Toxicity Analyses of Composite Samples

Sample	*C. dubia* lethality (% effect	*Ceriodaphnia* IQ (% effect)	Microtox (% effect)
comp #1	40	100	-1.67
comp #2	10	100	63.76
comp #3	10	100	14.35

These results indicate that compositing affects observed toxicity. The expected effect is a reduction in toxic response because samples with low concentrations of contaminants dilute the concentration of contaminants in the composite sample, producing a reduced toxic effect. This effect was observed in the composites from the February 26, 1996, storm event. There was a difference in the response of the three test systems. The *C. dubia* IQ test produced a similar effect in both individual and composite samples. The Microtox assay produced results that differed between individual and composite samples. In composites #1 and #3, the results reflect the dilution effect observed in the *C. dubia* results. In composite #2, the composite indicated high levels of toxicity while the individual samples showed stimulation.

The question of compositing in time-scale toxicity determinations should consider the study objective. If the objective is to use toxicity results to assess system response (e.g., first flush or concentration time analysis) or source identification, then time or flow sequenced sampling and analysis is preferred. If the objective of the study is a general assessment of toxicity to accompany an assessment of contaminant loading, then it is appropriate to perform toxicity tests on composited samples. It should be recognized that while compositing is appropriate for an assessment of contaminant loading, the compositing will tend to reduce toxicity by contaminant dilution and may lead to an underestimation of actual toxicity, particularly when short-term exposures may produce delayed effects.

7.6 Wet Weather Toxicity Questions

7.6.1 How Do I Characterize Intra-Event, Event, and/or Long-Term Toxicity? (Effect vs. Impact)

The tests used to characterize intra-event, event, and long-term toxicity must reflect the time scale of exposure likely to be experienced by receiving water organisms and the expected change in concentration in storm waters when closely spaced events result in relatively clean runoff for later events. For intra-event analysis, laboratory tests with exposure durations of minutes to a few hours are used, whereas for event analysis, laboratory tests with exposure durations ranging from intra-event time scales of a few hours to the 24–48 hour durations more typical of WET procedures may be used. For multiple events, single event results are integrated together to provide an overall picture (see Section 8.5). Samples for toxicity testing can be taken in-pipe and also in the receiving water to determine the effect of dilution on discharge toxicity. In situ deployments and in-stream assessments may also be used to verify the impact on the receiving water (see Chapter 8.0).

At the Kaufman Lake site an intensive monitoring program of the storm sewer discharge was carried out between 5/20/96 and 6/1/96. During this period, four storm events took place (5/23, 5/24, 5/26, and 1/6). Discharges from the storm sewer were monitored for the first and last of these events (Table 6-3), while receiving water was sampled throughout the period (see Table 6-4).

The first storm event showed high toxicity (87.4% light inhibition in Microtox and 80% fluorescence inhibition in the *C. dubia* IQ test). These toxic responses occurred in samples from the storm sewer taken within one hour of the start of the discharge (8:30 to 9:30), and a high level of light inhibition in the IQ test was evident at 9:30 in the downstream receiving water samples. Limited toxicity was measured in the storm sewer discharge for the last storm (14% light inhibition in the Microtox test and 0% fluorescence inhibition in the IQ test), and no toxicity was measured downstream.

In-stream monitoring showed that the number of invertebrate taxa at the upstream and downstream sites changed little before and after the intensive assessment period (Table 7-9). This indicates that long-term chronic effects might mask the effects of individual storms on the receiving water.

Table 7-9. Invertebrate Taxa at KLSS Upstream and Downstream Sites at Beginning and End of Intensive Campaign

Sampling date	No. of taxa at site	
	CSREF A site	DS MID site
5/21/96	4.7	3.0
6/4/96	5.7	3.7

7.6.2 How Many and What Type of Events Should I Sample to Characterize Toxicity?

At a given location, the number of samples must be sufficient to cover the potentially most toxic events and those likely to have an acute impact on the receiving water community. For instance, sampling should encompass times of highest runoff when contaminant delivery is greatest and at lowest receiving water flow when dilution is lowest. Transitional periods might require only limited or no sampling coverage. Event characteristics also vary by season. For example, storm events monitored in this study had different levels of total dissolved solids associated with the runoff of road deicing salts in the winter and late spring.

The number of storm events needed to identify wet weather effects depends on study objectives and the accuracy required by study design quality assurance. A general toxicity characterization can be achieved by applying standard sampling criteria (e.g., minimum of 72 hours after an earlier event and the event meeting runoff criteria) to one or two events. If seasonal variability is needed, then sampling is required for one or more events during each season. If source identification is an objective, multiple events can be sampled, or an extensive synoptic survey might be implemented for a single storm.

It is expected that storms of different size produce different levels of toxicity. In this research, storms were classified as small, medium, and large (see Section 2.3). This classification also related to expected frequency of return—small storms are more common. In selecting the number of storm events to sample, that number can be adjusted by storm size. A practical consideration in the study design is that it is easier to sample small storms, because they are more common, irrespective of the region (see Table 2-1).

The experience gained from this project indicates that an initial screening analysis is needed to identify toxic potential and that multiple storms should be sampled to confirm toxicity. This research also demonstrated that sampling closer to sources, even in-pipe sampling, provides a clearer picture of toxicity with fewer events needed to confirm expected toxicity. However, in-pipe toxicity does not necessarily equate to in-stream impact, which depends upon the dilution and dispersion available in the receiving water.

7.6.3 What Happens to Toxicity in Closely Spaced Events?

At a given location, the toxicity of events occurring soon after an initial event might not be pronounced if the majority of the available contaminants have been removed by the first event. At the Kaufman Lake site, an intensive monitoring program was carried out between 5/20/96 and 6/1/96 in which four storm events took place (5/23, 4/24, 5/26, and 1/6). The first and last of the storm-sewer discharges were monitored and while the first storm showed high toxicity, only minimal effects were measured in samples from the last storm (see Section 7.6.1).

7.6.4 Are There Some Events that Should Not Be Sampled?

Events occurring soon after an event that exhibited moderate or high toxicity might be inappropriate for sampling if the majority of the available contaminants was removed by the first event.

7.6.5 What is the Toxicity Associated with Rainwater?

Several studies have shown that rainwater an be toxic. This toxicity is not surprising, since rain droplets are known to remove particulates and water-soluble contaminants from the atmosphere.

In addition, natural rainwater is virtually free of dissolved solids producing a solution that has low hardness, and a low pH, which is associated with carbon dioxide dissolution. It has been well-described in toxicity testing that some contaminants, particularly heavy metals, are more toxic when hardness levels are low, or pH conditions favor the presence of biologically active forms of the contaminants. This project has documented the drop in conductivity in both runoff and stream flow associated with the runoff of rainwater. Extensive toxicity testing has not identified a consistent pattern that could be attributed to the inherent toxicity in the rainwater, but it is clear from fundamental chemistry and knowledge of rainfall characteristics that rainfall can affect conditions that affect toxic response.

When designing wet weather assessment studies, it is recommended that testing examine runoff from different portions of the event hydrograph using basic screening or advanced toxicity test systems. If toxicity is found in samples with low conductivity, testing should be considered to assess background rainwater toxicity.

7.7 Water Quality Questions

7.7.1 Where Do I Sample to Adequately Assess Water Quality?

Ideally, sampling points for water quality should be at, or in the vicinity of, the points at which samples are taken for toxicity testing.

7.7.2 Do I Need to Sample for Water Quality when the Objective of the Analysis is Toxicity Assessment?

Water quality analyses strengthen toxicity cause-effect relationships, if the test endpoint can be related to measured contaminant concentrations. As such, chemical analysis can be an important part of advanced screening or confirmatory testing. However, it should be recognized that this is not always feasible where complex mixtures of contaminants are involved and that the whole rationale for toxicity testing results from the limitations of using chemical analysis alone as a tool for monitoring stormwaters. Information on basic physicochemical parameters of samples, such as pH, dissolved oxygen, hardness and conductivity, are important for the interpretation of toxicity data, particularly when the causative agent or agents of toxicity are being evaluated.

7.7.3 Why is Continuous Monitoring of Some Parameters Essential?

It is essential to have continuous monitoring of certain parameters, such as stage height, conductivity and dissolved oxygen, to be able to interpret when storm events start and the nature of that event in relation to others over time at a site or between events at different sites.

7.7.4 What Water Quality Changes are Typical of Storm Events and How are These Related to Changes in Toxicity?

This research identified that conductivity was the most reliable indicator of changing water quality during storm events. At KLSS, storm events typically were associated with a decreasing then increasing conductivity, indicative of the passage of low conductivity rainwater dominating the runoff. In addition, spikes in conductivity were often observed during events indicating first flush effects, or the effects of concentration time in a system where increased dissolved solids passed the sampling point.

The water quality changes that were observed during this project were highly variable and dependent on receiving system type and characteristics, location in the watershed, season, antecedent conditions, and storm characteristics.

7.8 Sources Questions

7.8.1 Must I Do Anything Special to Sample or Analyze for CSO/SSO/Urban Runoff Effects?

Stormwaters have unique characteristics based upon source characteristics. Combined sewer overflow (CSO) and sanitary sewer overflow (SSO) sources originate from sewers carrying wastewater and can be expected to contain a full range of common wastewater pollutants. In addition, these "sewer" sources of stormwater have higher concentrations of certain pollutants, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), pathogenic bacteria, etc., that might be expected in general urban runoff or rural/agricultural nonpoint runoff.

Because of the higher oxygen demand expected in some CSO/SSO samples, it might be necessary to adjust toxicity testing procedures and possibly include aeration. At a minimum, special attention should be given to oxygen monitoring in screening and advanced testing with CSO/SSO samples. Urban runoff is affected by watershed land use, and the presence of certain land uses can direct analysis to specific parameters, or lead to the selection of test systems most suitable for expected, or known parameters.

The protocol for test system selection is designed to accommodate samples of different quality and characteristics. In general, no special sampling is required for basic screening analysis, although special sampling might be required as advanced testing is implemented to meet specific analysis objectives.

7.8.2 What Do I Need to Know About a Watershed to Identify Sources?

To identify sources of toxicity in a watershed it is important to know about the pattern of land use contributing to storm water runoff. Knowledge of general land use activities, such as agricultural, industrial, roads, or residential, in the watershed allow an assessment of the types of contaminants likely to be present. This information can also be useful where there are seasonal applications of substances in certain locations that might result in seasonal stormwater toxicity.

It is also useful to have specific information on industrial and other commercial activities to pinpoint likely inputs of known contaminants. This information can then be tied into the findings of toxicity testing to identify sources.

7.8.3 How Do I Identify the Source of an Observed Effect?

Toxicity tracing from an outfall back up the system might allow the source of the toxicity to be identified, while the use of TIE procedures can allow the causative agent(s) of toxicity to be investigated (see Section 7.9.8). Use of a storm sewer model, which predicts flow times through different areas of a watershed, in conjunction with time-sequenced sampling, helps identify possible sources of toxicity. Information on the use of storm sewer models to trace the sources of toxicity and the use of TIE with basic screening tests are described in Chapter 5.0 and Appendix B.

7.9 Interpretation and Analysis Questions

7.9.1 How Do I Interpret the Data from Basic Screening Tests?

Interpretation of the data from basic screening tests initially involves determining whether there have been storm-related effects, that is whether the test systems have responded to stormwater samples. If responses are detected, it is then necessary to determine whether these responses are considered to constitute toxicity and to classify the storm based on the extent of the responses and then to identify whether additional advanced or confirmatory testing is needed. Responses in basic screening tests can only be regarded as biologically meaningful if an impact on the receiving water biota is found to result from stormwater discharges.

7.9.2 How Do I Decide from Basic Screening Test Data If a Discharge is Toxic?

In basic screening tests, the responses of test organisms (as light output in the Microtox test, fluorescence in the IQ test, and lethality in mortality tests) in undiluted samples are initially measured. Stormwater samples from intra-event or event analysis are regarded as showing toxicity if responses in test systems exceed 20% (see Section 3.4.3). Note that toxicity shown in a wet weather discharge sample should not be used to define an impact source. Confirmation of the cause of an observed impact should consider receiving system dilution of the discharge receiving water testing to eliminate upstream, or other possible, causes of an identified impact.

7.9.3 How Do I Use Intra-Event Analysis to Identify Where Toxicity Occurs in a Storm?

For intra-event analysis of storm sample, datas should be used to identify where test responses exceeded 20% either as direct measurements for in-pipe samples or by comparison with pre-storm values where samples were taken in the receiving water near the discharge (see Section 3.4.3).

The measured responses in a test during the event can be compared statistically against the background pre-storm values using either parametric (for example, analysis of variance [ANOVA]) or non-parametric (for example Kruskal-Wallis) multiple comparison techniques depending upon whether the data are normally distributed and the variances of test groups are homogeneous. If a single composite sample is taken in the receiving water during a storm event, test organism response should be compared with those measured in a pre-storm sample using an appropriate parametric or non-parametric two-sample statistical analysis.

7.9.4 How Do I Classify Discharges on the Basis of Basic Screening Test Data?

In the protocol, the scheme for classifying storm events based on in-pipe sampling (see Table 3-1) involves considering:

- The extent of toxicity measured in samples;
- The consistency of response between tests;

- The percentage of samples showing toxicity; and
- The position of these in the hydrograph.

Toxicity during a wet weather event is variable, and, by taking account of frequency and consistency of response, the classification takes account of samples showing high toxicity, but reduces the influence of extreme values for individual samples on the toxicity classification. This achieves a balance between recognizing that events are variable and minimizing false positives. Section 5.2 reviews research that establishes post-exposure effects resulting from brief exposures. Furthermore, averaging low or no toxicity samples tends to underestimate toxic potential. That said, any extreme or atypical values might require further investigation, perhaps by re-testing with alternative tests or organism batches, to ascertain whether the results are genuine.

For event analysis, classification is based upon the extent of the toxicity measured in samples and the number of tests in the battery responding.

For each discharge, there is usually a series of storm classification measures, since data are available from a series of storm events. It is expected that discharges from a single pipe will show varying degrees of toxicity from one storm to another, depending on a wide range of factors, such as intensity of rainfall, antecedent dry period, recent pesticide application, sensitivity of test organisms, etc. Since the concern is with the toxic potential of the discharge, the actual classification should be based on the highest observed toxicity across storm rather than an average of the toxicity determinations for all storms. Again, any extreme values should be investigated to minimize the risk of false positives, because although variability in toxicity is to be expected, classification should not be based upon isolated and unverified responses. For example, if a discharge point consistently shows no toxicity then shows high toxicity for a single storm event, this might warrant investigation. The degree of confidence associated with any estimation of toxic potential depends on the nature of the results from multiple storms and on the results from multiple elements of the test battery, considering both frequency and consistency of response. Field observation on actual in-stream impacts is also important in validating conclusions drawn from such results.

An initial toxicity screen should be used to design a program that determines the toxicity category (moderate/high, specific/general, infrequent/intermediate frequency/frequent) and also determines whether advanced screening is needed.

Using this toxicity classification system, moderate levels of toxicity have generally been measured at KLSS, though the storm sewer would be classified as having the potential for high toxicity based on the 5/23/96 sample (see Table 7-10). The Cleveland sites and Pylon site at Fort Worth would be classified as of moderate toxicity, while the Cra site in Fort Worth would be classified as highly toxic. For sites where samples have been taken in-pipe, the available dilution/dispersion in the receiving water needs to be considered to determine whether there is likely to be an impact and whether advanced screening is needed. When toxicity was evident in the *C. dubia* IQ test, it was observed in most samples taken through the storm, whereas for the Microtox test, toxicity was usually only found in a limited number of samples.

Table 7-10. Microtox and *C. dubia* IQ Data for Intra-Event Analysis of Different Storms at Various Locations and Resulting Classifications

Location	Date	Maximum toxic response measured (%) Microtox (20 min.)	Maximum toxic response measured (%) *C. dubia* IQ (1 hr)	Classification of storm event
KLSS	7/4/95	0	90	Moderate/specific/frequent/first flush & peak
	7/23/95	55	90	Moderate/general/frequent/first flush and peak
	10/23/95	25	85	Moderate/specific/frequent/ first flush and peak
	2/26/96	57	40	Moderate/general/intermediate freq./first flush & peak
	3/24/96	24	50	Moderate/general/intermediate/peak
	5/23/96	87	80	High/general/intermediate/peak
	6/1/96	14	10	No toxicity
	7/14/96	70	80	High/general/intermediate frequency/first flush
	7/21/96	48	0	Moderate/specific/intermediate frequency/first flush
Cra (Ft Worth)	5/24/95	47	87	Moderate/general/frequent/first flush & peak
	5/27/95	0	90	Moderate/specific/intermediate frequency/peak
	7/9/96	76	22	Moderate/specific/frequent/first flush & peak
	8/9/96	81	100	High/general/frequent/first flush & peak
Cleveland				
SS-01	7/16/96	15	100	Moderate/specific/frequent/first flush & peak
SS-02	"	1	90	Moderate/specific/frequent/first flush & peak
SS-03	"	5	100	Moderate/specific/frequent/first flush & peak
SS-04	"	0	80	Moderate/specific/frequent/first flush & peak

7.9.5 What Course of Action Should Be Followed for Discharges Showing No Toxicity in Basic Screening Tests?

An absence of toxicity in storm events indicates that it is possible to eliminate this site from further toxicity testing. In fact, it suggests that scarce financial and personnel resources could better be applied to other locations or other aspects of a stormwater management program. As with toxicity screening following US EPA procedures, some continuing monitoring might be needed to confirm that no changes occur in toxicity potential.

7.9.6 What Course of Action Should Be Followed for Discharges Showing Moderate or High Toxicity in Basic Screening Tests?

The presence of moderate or high toxicity in samples taken in the receiving water is a clear indication that conditions associated with wet weather discharges are cause for environmental concern. A logical first step is to determine if known wet weather sources are the source of toxicity. A second critical need is to determine the environmental significance of known sources, which might require watershed assessment and advanced screening. Advanced or confirmatory testing should only be carried out on samples that show moderate or high toxicity to more than one test of the screening test battery. This approach ensures that resources will not be used inappropriately and effort directed unnecessarily to false positive samples.

If a discharge is judged to have the potential for moderate toxicity, then it is necessary to consider more advanced tier testing. This advanced tier testing can be designed for several purposes. The first would be to identify the toxic agent and, through that identification, the likely source of contamination. Another option would be to use the measured toxicity to direct longer term testing, such as in situ tests to assess more subtle effects and possible cumulative effects of multiple storms. When a laboratory program identifies stormwater samples as toxic, a critical adjunct step is to ascertain to what extent the receiving water biota are affected. It is clear that moderate levels of toxicity present the greatest difficulty to both testing/assessment activities and management.

If high levels of toxicity are observed in time-sequenced storm samples from a discharge, the need for advanced tier testing is greater. First, the advanced tier testing should involve some type of TIE procedure to clearly identify the cause of toxicity and, again, the possible source. Time-scale toxicity testing can also be used to develop duration values critical to the observed toxicity. Findings of high levels of toxicity present the least difficulty in defining advanced tier testing and management priority.

7.9.7 How Do I Use Advanced Screening Tests to Clarify the Extent of Toxicity Measured in Basic Screening Tests?

The extent of responses measured in stormwater samples with basic screening tests can be confirmed by conducting concentration-response tests. The derivation of $EC(LC)_{50}$ values from these tests can provide a better indication of the toxicity of stormwater samples than that available from the test responses in undiluted samples. For example samples taken at 12:00 and 12:20 during the 7/4/95 storm at KLSS showed 90% and 60% inhibition of fluorescence in the *C. dubia* IQ test and were subsequently tested using *C. dubia* IQ concentration-response tests. Table 7-11 shows the concentration ranges tested, the test responses, and the EC_{50} values derived. The lower EC_{50} value for the 12:00 sample compared to the 12:20 sample confirmed the pattern of response seen in the undiluted samples.

Table 7-11. *C. dubia* IQ Data from Concentration-Response Tests on Stormwater Samples from the 7/4/95 Storm at KLSS

Sample	% inhibition of fluorescence to *C. dubia* in undiluted samples	% inhibition of fluorescence at different concentrations (% sample)				EC_{50} (%)
		0	25	50	100	
12:00	90	5	45	75	95	28
12:20	60	5	20	45	80	52

The use of concentration-response tests is particularly valuable where a number of samples show the same level of response in undiluted samples but may show markedly different $EC(LC)_{50}$ values.

7.9.8 How Do I Use Advanced Screening to Identify the Cause of Toxicity?

The cause of moderate or highly toxic storm events can initially be investigated using the toxicity characterization element (Phase I) of the US EPA toxicity identification evaluation (TIE) procedure. Toxicity characterization involves separating the stormwater sample (and a dilution water control) into a series of fractions using processes, such as aeration, filtration through glass fiber filters, ^{18}C solid phase extraction, oxidant reduction, ethylenediamine tetraacetic acid (EDTA) chelation, and graduated pH adjustment. The KLSS consistently showed moderate toxicity during storm events, and a TIE was carried out on the 15:00 sample from the 4/25/96 storm, which initially caused 44% light inhibition in the Microtox test and 100% inhibition of fluorescence in the *C. dubia* IQ test. Toxicity characterization was carried out with the Microtox test according to the US EPA procedure described in Appendix B and indicated that the toxicity observed could have been due to a combination of volatile materials and heavy metals.

A TIE carried out on Cra storm sewer discharge (Waller et al., 1995) indicated that toxicity was due to the presence of elevated heavy metal levels, particularly zinc, which probably arose from a nearby metal plating facility. Subsequent analysis of heavy metal concentrations in discharges showed that these levels were sufficient to account for the responses measured in the Microtox tests (see Table 7-12).

Table 7-12. Comparison of Maximum Microtox Responses during Storm Events with Measured Zinc Concentrations

Date of storm	Maximum response (% light inhibition)			Zinc concentration in sample (mg/L)	EC_{50} for zinc (mg/L)
	5 mins	10 mins	20 mins		
5/24/95	16	23	47	1.27	1–2.5 (20 mins)
7/9/96	69	73	76	3.53	

The Microtox data show that light inhibition increased with increasing exposure time—evidence that the contaminants causing the response were probably dissolved heavy metals (see Section 6.3). As noted previously, information on the physicochemical parameters of samples is important in interpreting data and ascertaining the cause of toxicity. For example, sample pH and hardness have a marked effect on the toxicity of heavy metals.

7.9.9 How Do I Separate Wet Weather Effects from Other Watershed Influences in Receiving Water Samples?

The contribution of stormwater discharges to in-stream toxicity can be assessed by measuring responses in receiving water samples taken at both upstream and downstream sites as a time-sequenced series before, during, and after the storm. Identification of the impact of the storm water discharge is easiest where there is consistently limited toxicity measured at the upstream site. Analysis is complicated where there is considerable background variability in the responses observed in upstream samples outside of storm events.

Table 6-4 shows the responses in water samples from locations upstream and downstream at the KLSS measured with the Microtox and *C. dubia* IQ tests during an extended sampling program. The survey was carried out between 5/20/96 and 6/2/96 and 4 storm events. The upstream reference site

(CS REF) was on the Copper Slough approximately 50 m above the confluence with the KLSS basin, while the downstream site (DS MID) was about 100 m downstream of the confluence.

Responses in water samples at the upstream reference site were generally limited (<10 % change from pre-storm level) in both the Microtox and *C. dubia* IQ test with the exception of samples taken within a 4-h period of the start of the storms on the 5/23 (8:30) and 1/6 (17:20). These transient increases in toxicity above baseline levels probably resulted from the presence of contaminants which had entered the Copper Slough system upstream and been washed down to the reference site. Samples taken at the downstream site showed increased toxicity in the *C. dubia* IQ test immediately following the start of the 5/23 storm (that is in the 9:30 sample). Three hours after the start of the storm, the elevated toxicity seen in the *C. dubia* IQ test probably reflected the movement downstream site of contaminated water from the upstream site. Subsequent storm events resulted in no toxicity in water samples taken from the downstream site. The absence of toxicity at the downstream site following the 5/26 and 6/1 storms was consistent with the lack of toxicity measured in the samples from the storm sewer (see Table 6-3). The absence of toxicity in the storm sewer samples taken for the 5/26 storm probably reflects the limited availability of contaminants from runoff after the 5/23 storm. It indicates that it might not be worth sampling storms occurring rapidly after an initial event if that initial storm showed high toxicity (see Section 7.6.4).

Assessment of receiving water samples at the upstream (US) and downstream (DS) stations on the Copper Slough consistently showed an absence of toxicity (see Tables 6-3 and 6-4) probably due to the dilution of the storm-event discharges on the receiving water.

7.9.10 What is the Relationship of Wet Weather Toxicity to Dry Weather/Baseline Flow Toxicity?

The relationship of wet weather toxicity to baseline flow toxicity is site-specific and can be quite complicated. At one level, wet weather toxicity simply represents an acute response associated with the concentration and duration of exposure to contaminants during a storm event. Laboratory testing has verified that even short exposure durations can produce effects after the storm event has passed (see Chapter 5.0). Therefore, toxicity observed after an event, such as a fish kill days following a storm event, might be related to storm conditions and not base flow.

The relationship of wet weather flow toxicity to baseflow toxicity has been evaluated by Crunkilton et al., 1996. In their study, *Daphnia magna* and *P. promelas* were exposed for up to 14 days. Crunkilton noted, "There were no apparent differences in toxicity of organisms exposed to base flow and those that were exposed to high flow. Both were equally toxic." The critical finding in this research was the effect associated with extended exposure where seven-day tests indicated no effect and fourteen-day tests showed significant effect.

7.9.11 Does Toxicity Vary Seasonally?

At a particular location, seasonal differences in toxicity can result from event-specific characteristics, such as the length of the antecedent dry period, the intensity of rainfall, changes in the nature of deposition of materials on urban surfaces or the use of chemicals on residential or farm land, as well as receiving water characteristics (e.g., volume). However, given the potential interaction of these different factors, it might be difficult to clearly identify seasonal factors.

A simple approach would be to divide monitored storms into seasonal categories and examine the maximum responses observed in toxicity tests. This analysis was performed for data from KLSS, but no differences between seasonal toxicity were evident.

7.9.12 Does Toxicity Vary by Location within the Watershed?

For a specific event, differences in toxicity of runoff entering the receiving water system are found at various locations in a watershed due to the differences in the nature of the inputs. On a standardized loading basis, the magnitude of contaminants entering a receiving water varies according to land use and results in different levels of toxicity given the same degree of dilution. The general order of contaminant loading for different land uses from the highest to the lowest is: industrial and commercial > freeway > higher density residential > lower-density residential > open land (Horner et al., 1994). This pattern was found for basic screening tests on runoff samples collected from different land types in Fort Worth, Texas, during May, 1995 (Table 7-13). Samples were taken from the following watersheds:

- Cra, which is approximately 47 acres and dominated by industrial land use;
- Pylon, which is approximately 28 acres and contains and agricultural land use; and
- Eastern Hills, which is approximately 154 acres and consists primarily of residential areas.

The data showed that, for water samples collected from the three sites during a storm event on 5/24/95, the responses in the Microtox and *C. dubia* IQ test were most marked for Cra samples with less toxicity being recorded for the Eastern Hills and Pylon samples.

Table 7-13. Toxicity Data for Storm Event Samples Taken on 5/24/95 from Sites with Different Land Uses in Trinity River Watershed (Fort Worth)

Site	Toxicity (% response) for the 5/24/96 storm event	
	Microtox	*C. dubia* IQ
Cra	100	87
Eastern Hills	36	70
Pylon	0	30

In the receiving water, differences in toxicity at different locations can result from the volume of the receiving water and hence the available dilution at a given location.

7.9.13 Does Toxicity Vary by Region?

Toxicity differs between watersheds in different regions because of the different uses of land within those watersheds. However, for runoff samples derived from specific land uses in different regions, differences in toxicity can result from different storm event characteristics, such as rainfall intensity. In urban areas, snowmelt and the release of salt to receiving waters is a major issue in many States, but not Florida, Texas, etc., which are not subject to extreme climatic conditions.

The regional testing conducted for this project indicated that no fundamental differences in the characteristics of the toxic response to wet weather events could be attributed to specific regional characteristics. The differences in toxicity appeared to be source- and site-specific, and generally tracked a response pattern that identified both first flush and later responses, which can be attributed to resuspension of contaminants. In general, regional differences in toxicity are not of major concern, although adjustment of test procedures to accommodate regional differences in hydrology (see Table 2-1) might be needed.

CHAPTER 8.0

FIELD-BASED STORM EVENT ANALYSIS

8.1 Assessment Design Questions

8.1.1 When Do I Use In Situ Tests or Biosurveys?

Within the time-scale and biological tier testing framework, in situ tests and biosurveys find application in the event and long-term time scales and in the advanced screening and confirmatory testing tiers (see Chapter 3.0). In situ bioassays and biosurveys gives a measure of actual in-stream effects and serve as a link between laboratory-based measures (both biological and chemical) and possible ecological degradation. When a laboratory program identifies stormwater as being toxic, a second, critical step is to ascertain the actual environmental impact. In some situations, for example where receiving water dilution capacity is large, acute toxicity of stormwater might be of little or no consequence in terms of environmental degradation. Laboratory toxicity testing of receiving water samples obviously will give an indication of whether or not this is the case. However, any laboratory testing brings an artificiality to the analysis, thereby reducing its ecological relevance. Therefore, field assessments should be undertaken as a confirmatory exercise to evaluate in-stream impacts.

Studies of in-pipe toxicity at the KLSS site consistently showed moderate levels of toxicity occurring in most storms (see Table 6-4). Additionally, laboratory toxicity testing of in-stream water samples showed that toxicity was also present downstream and sometimes upstream of the point where the storm sewage discharge entered the main Copper Slough Channel (see Table 7-2). Biosurveys were undertaken at sites along the Copper Slough to ascertain the in-stream impact of the discharges (see Section 8.4), with invertebrates being sampled on three occasions using both Surber samples and kick samples.

8.1.2 When Shall I Perform an In Situ Test as Opposed to a Biosurvey?

The use of field-based assessments fits into a sequenced application of the tools available for wet weather event impact assessment. First, biosurveys should be used early in a wet weather assessment program to confirm that an in-stream impact exists. In fact, biosurvey findings often are the first indication that degradation due to storm events has occurred. Alternatively, following the identification of toxicity of a storm discharge through laboratory toxicity testing, a biosurvey can confirm whether or not receiving water is impacted. Biosurveys results can be used to tailor in situ or laboratory tests to the receiving water system by basing the choice of test organisms according to what is actually present in the receiving system.

Biosurveys generally provide the most ecologically relevant information of any type of biological testing. However, finding a receiving water impact downstream of a discharge does not necessarily imply a cause-effect relationship to a particular discharge, although it can provide strong evidence for such a relationship.

In contrast, in situ exposure experiments can be used to provide evidence of the impact of a wet weather discharge through a more controlled experiment. An exposure experiment yields the most direct evidence of a cause-and-effect relationship between storm events and in-stream effects. Exposure experiments can also be used in place of biosurveys where the natural fauna are severely impoverished due to degraded or poor quality habitat, or where marked differences in habitat preclude the selection of comparable sites for biosurvey sampling. See also Section 8.4.1.

8.1.3 Where Shall I Deploy In Situ Tests or Conduct Biosurveys?

Precise details of where to deploy in situ tests or conduct biosurveys depends largely on the study objectives and the constraints imposed by the receiving water system itself. However, a number of points must be considered.

For both biosurveys and in situ assessments, the position of sites relative to discharges is important. Firstly, appropriate reference sites are required (see Section 8.1.4). Secondly, downstream sites must take account of the physical mixing zones of discharges. A site within the immediate mixing zone might be required to examine maximum impact, but, for assessing the wider downstream impact, sites should be outside the immediate mixing zone. However, defining mixing zones is complex, and no simple guidance can be given. A third factor that should be considered when selecting sites is the danger of pseudoreplication (Hurlbert, 1988), which is the erroneous attribution of apparent differences between sites to some factor other than the true cause. This problem arises through inadequate sample replication. In situ tests and biosurveys are particularly prone to the dangers of pseudoreplication; for example, differences between a single upstream and a single downstream site could be ascribed to the impact of a discharge but in fact may be due to some other, unmeasured or unknown, factors, such as habitat differences. The use of multiple sites does not directly avoid this problem but goes some way towards avoiding erroneous conclusions.

For biosurveys, the prime consideration for selecting the exact sampling locations is site similarities. Since the objective is to compare the resident fauna or flora at two or more sites, and one of the major determinants of biological community structure is the physical habitat available, it follows that for comparisons to be meaningful, similar sites must be used. Indeed, the effects of changes in habitat can result in far greater differences in biological communities than the effect of considerable levels of contamination.

For in situ exposure assessments, site similarities are less critical but still of importance. Every effort should be made to select sites that are similar in physical factors that might effect organism health and survival, such as water depth, current velocity, shading. Figure 6-2 shows the deployment locations for in situ tests and biosurvey sampling locations on the Copper Slough Watershed.

8.1.4 What Constitutes a Reference Site?

A reference site is one that is used for comparisons with an impacted site. Two different types of reference sites exist and serve different purposes.

A **local or upstream reference site** is one that is used for direct comparison with an impacted site to infer the effect of a single discharge, multiple discharges, or runoff zone. Typically, this is a site that is upstream of the impacting discharge, or impacted area. The results from in situ deployments or biosurveys at this site are compared with results from the downstream, impacted site. Although an upstream reference site allows the identification of the impact of a particular input, it does not allow an identification of the impact of other input sources or a general degradation in water quality. Such a distinction may be assisted by use of a general or background reference site. In the KLSS system, the local reference site (CS REF) was located about 50 m upstream of the confluence of the outlet of the KLSS basin (see Figure 6-2).

A **general or background reference** site is one that is free from (major) anthropogenic influence and, as such is a measure of natural background conditions. By comparing the results of in situ deployments or biosurveys at a general reference site, an upstream reference site, and an impacted site, it is possible to infer the relative importance of the impact of the input under study in relation to that caused by other inputs. A reference site might be situated in the upper reaches of the watershed, above known inputs, or on a different, unimpacted stream. Clearly, the problems arising through pseudoreplication and the influence of other, unknown factors are likely to be greater for sites at some distance from each other, so greater care is required when interpreting results.

The Water Environment Research Foundation has published reports that discuss selection of reference reaches for use attainability analysis (Novotny et al., 1997; Michael and Moore, 1997). Much of that information would likely apply in this context. See also Section 8.1.5 of this report.

8.1.5 What Action Should I Take if a Suitable Reference Site Cannot Be Identified and Sampled?

A control site is essential for a meaningful interpretation of the results of in situ deployments of biosurveys. Without a control site, it is impossible to reliably attribute any measured effect to the storm water input(s) under investigation.

In the case of biosurveys, if a suitable control site cannot be identified (habitat dissimilarities), it might be appropriate to use an in situ technique instead. Another possibility is the use of artificial streams, but cost generally makes this an impracticable option.

With the advent of biocriteria, reference sites are now a critical component of water quality regulation and a focus of some controversy. Many States, in response to biocriteria development efforts, have identified reference streams and reference conditions. It might be possible to apply information from these non-degraded reference sites to evaluate biosurvey results.

8.1.6 When and Where Are Sediment Analysis/Assessment Efforts Needed?

Sediment toxicity assessment adds an important dimension to in situ water column toxicity assessments. Sediment toxicity is generally a chronic phenomenon resulting from sediment build-up over relatively long time scales. Thus, sediment assessments fall into the multiple event/ long-term area of the time-scale matrix.

Sediment assessments are most appropriate when significant sediment has accumulated in the receiving system and when there is interest in sediment-associated contaminants, such as heavy metals and organics. Sediment analysis might be also needed where resuspension of a significant amount of material that is known to, or suspected of, contributing to water quality problems has occurred. See also Section 8.5.1.

8.2 Sampling Questions

8.2.1 How Many Measurements Must I Take?

The number of measurements that must be made to answer a question is dependent on the precision required, the variability of the measurement process and the samples, and cost constraints (see Section 7.2). If the variabilities of the measurement process and of what is being measured are known, statistical techniques are readily available for calculating the required number of samples to attain a specified precision. This also allows estimation of the statistical power of the test to detect a given difference, i.e., the probability of concluding there is an effect when one exists. Discussions of the statistical aspects of sampling program design can be found in Mar et al., 1986; Reinelt, Horner, and Mar, 1988; Reinelt, Horner, Castensson, 1992; Horner et al., 1994.

A problem with in situ assessments and biosurveys is that the samples are usually highly variable, and variabilities are often unknown. A good starting point for deciding how many measurements to take or how many replicates to use is to assess what was done in other similar studies and how successful they were in achieving the stated objectives.

8.2.2 How Much Do Field Assessments Cost?

The cost of field assessments is quite variable and, again dependent on study objectives that define the effort and expertise required in a field assessment. The US EPA has developed Rapid Bioassessment Program (RBP) guidance (US EPA, 1989; also available from www.epa.gov/ OWOW/monitoring/AWPD/RBP/ bioasses.html) that has five protocols that require different levels of effort and expertise. These different levels of effort and expertise will have significantly different costs. For example, the level of effort for a RBP 1, a subjective analysis, is estimated to be 1 to 2 hours per station with an additional 0.5 to 1 hour for data analysis per station. Costs for this level of analysis might be as low as $200 to $500 per station. As assessment requirements increase, the level of effort and expertise costs increase. A typical screening level test involving macroinvertebrate sampling and analysis (e.g., identification to the family level for initial metric determination) costs from $500 to $2,500 per station. Addition of fisheries collections and identification of samples to the genus or species level add significantly to assessment costs. These estimates are for RBP sampling and would not include the cost of chemical analysis or supplementary toxicity testing.

8.2.3 Are Unique Devices Needed to Perform In Situ Testing or Biosurveys?

In situ deployments most commonly involve the placing of organisms in cages within the receiving system. There are no standard devices for this purpose but a number of workers have successfully used similar types of design (see Herricks, Milne, and Johnson, 1994).

For invertebrates, a small tube (usually perspex) is used, either with mesh over the ends or with sealed ends and mesh-covered openings cut into the tube. The precise size of the tube is not critical, and the number of organisms per tube can be adjusted according to the relative size of organism and tube, though many invertebrates are cannibalistic and, therefore, require individual cages. The individual tubes are usually aggregated into groups in some kind of cage or basket, which is fastened to the stream bed (e.g., with stakes) or attached to a weight (e.g., concrete block). The design and orientation of the cages in the stream must be such that sufficient water flows through but not at a velocity that might be excessive for small invertebrates, such as *Ceriodaphnia* (Sasson-Briskson and Burton, 1991).

For fish, larger cages are required and these can be constructed from a number of materials. The only important design requirement is that there is adequate flow of water and food particles.

Other types of in situ assessments include colonization samplers. These can consist of natural materials, e.g., stones held in a coarse mesh container or be of entirely artificial construction. Purpose-made colonization samplers are commercially available.

For biosurveys of invertebrates, a number of standard sampling devices are available. The commonest is a simple pond net used for kick sampling, which may have specified dimensions for the mouth and the mesh size. Others are devices, such as Surber samplers, that enclose a quadrant, with an integral net to trap dislodged organisms. For deeper water bodies, a variety of grab samplers can be used from the bank or a boat.

8.2.4 Which Organisms are Best for Field-Based Wet Weather Analysis?

In theory, any organism could be used for field-based wet weather event analysis. In practice, invertebrates and fish are most commonly used.

For in situ assessments, invertebrates are preferred over fish, because they are usually more easily collected and/or cultured and require smaller, simpler cages. Usually, organisms are deployed without food, and the maximum holding time before death ensues must be taken into consideration when selecting a test organism. For *Ceriodaphnia*, this period is 48 hours, while for *Hyalella* and similar species, and also for fish, it is around one week. Invertebrate shredders, such as *Hyalella*, can be provided with leaf material as a food source, allowing a longer deployment period.

For biosurveys, invertebrates are generally preferred to fish for several reasons. First, they are much easier to sample. Secondly, being less mobile, invertebrates provide a truer picture of recent water quality. Although invertebrates respond rapidly to adverse conditions and move away from an area by drifting, recolonization is a much slower process, requiring several weeks at least. In contrast, fish very rapidly move in response to short-term adverse conditions, such as a storm event. Also, there are well developed biotic indices based on invertebrates that provide a single index from a more complex data set. A disadvantage of invertebrates compared with fish is that sample processing and identification is much more labor intensive (see also Section 8.6).

8.2.5 How Long Should I Expect to Maintain a Sampling Program to Assess Effect?

The duration of a sampling program is largely defined by the study objectives. The use of in situ assessments and biosurveys is primarily be directed at multiple event/long-term time-scale analyses. There might be seasonal factors affecting toxicity of stormwater, (e.g., seasonal application of pesticides, seasonal storm patterns, snowmelt) which require a sampling program to cover a whole year or certain parts of the year. In situ assessments probably have a duration of weeks to months, while a biosurvey program might be ongoing for months to years.

8.3 Sources Questions

8.3.1 Do I Use Different Techniques for Different Sources?

Generally, sources are not a major factor in the selection of techniques, although knowledge of sources can direct choice. The presence of primarily non-conservative contaminants directs the focus of field assessments to event time-scale analyses, while the presence of conservative contaminants call for long-term analyses. Where a problem is known or suspected with heavy metals or organics that bind to particulate matter or accumulate in tissues, sediment tests or bioaccumulation studies might be necessary.

8.3.2 What Must I Know about Sources to Effectively Develop a Field Analysis Program?

It is desirable, but not essential, to know something about sources. Knowledge about possible toxicity sources (and, therefore, contaminants) can aid in the selection of the organisms for an assessment program. The presence of a particular contaminant should lead to the use of organisms with known sensitivity to that contaminant. For example, where ammonia is considered to be the causative agent of toxicity, fish should be used rather than invertebrates due to their greater sensitivity. In contrast, invertebrates would be more appropriate where pesticides are the suspected causative agent of toxicity.

8.3.3 How Do I Separate/Compare the Effects of Multiple Sources in a Field Analysis Program?

This is an area where understanding is poorly developed and relationships are not well understood. However, responses of particular in situ test systems and test organisms, as well as biosurvey results, might indicate differential effects of particular sources. For example, bioaccumulation studies might establish a link with a certain contaminant, possibly of particular origin. Similarly, differential responses of organisms in the community can lead to particular sources through knowledge of differing sensitivities to particular contaminants.

8.4 Wet Weather Event Questions

8.4.1 When and How Do I Use In Situ or Biosurvey Techniques for Event, Multiple Event, and/or Long-Term Analysis?

8.4.1.1 In Situ Tests

In situ assessments can fairly readily be used for event and multiple event analysis provided there is an intensive, rolling deployment program that extends over a number of months. Because events are unpredictable except in the very short-term, it is necessary to have a deployment in place, with frequent observations being taken before an event occurs so that pre-event observations can be compared with post-event observations. For long-term analysis of toxicity at a location, the rolling deployment program might need to be carried out for a year or longer. Where the time scale of interest is event, tests with relatively shorter induction times are most appropriate—for example lethality-based tests and feeding rate tests. For the multiple event and long-term time scales, these event-time-scale tests might still apply when deployed in a rolling program, as well as tests with relatively longer induction times, such as bioaccumulation tests and colonization chambers. The use of in-stream assessments is an important link between the laboratory measurement of toxicity in samples from a stormwater discharge and ecological effect, and these techniques are used primarily in a confirmatory role.

The effects of the 6/1/96 storm at KLSS were investigated using in situ tests with the invertebrates, *D. magna* and *H. azteca*, and fathead minnows (*P. promelas*). Organisms were deployed at the Copper Slough reference site (CS REF) and in the KLSS basin with sediment and without sediment (water column only) on 5/31/95 and recovered 48 hours later after the storm event. The results showed that for water column exposure, lethality was significantly higher (t-test, $P<0.05$) in the *D. magna* and *H. azteca* deployed in the KLSS compared to those at the reference site (see Table 8-1). However, no toxicity was measured in the discharge during this storm event, and the water column toxicity might have been due to the resuspension of contaminants present in the sediment at this site. For fathead minnows, there was no statistical difference between the lethality in organisms deployed at the two locations. Lethality in the organisms deployed at the reference site was less than 20% for all test species.

Table 8-1. Toxicity Data for In Situ Water Column Tests Deployed at KLSS for the 6/1/95 Storm

Location	Lethality (%) in different in situ tests		
	D. magna	*H. azteca*	*P. promelas*
CS - REF	20	17	10
KLSS Basin	100	46.7	6.7

A variety of caged invertebrates were deployed at the US and DS stations on the Copper Slough, but none showed storm-event-related toxicity responses. The lack of response at these stations suggested that the events did not cause toxicant concentrations that were sufficiently elevated to cause mortality over the short exposure periods during events.

During other studies, the project team has investigated the effects of CSOs at two sites in the United Kingdom: Pendle Water (Lancashire) and the River Trent (Staffordshire) (Milne et al., 1992). At Pendle Water, metal accumulation and mortality in caged amphipods (*Gammarus pulex)* and metal accumulation in resident mayflies (*Baetis rhodani*) were measured. On the River Trent, mortality in caged *G. pulex*, brown trout (*Salmo trutta*) and chub (*Leuciscus cephalis*) were used.

Deployments of caged *G. pulex* at sites above and below a CSO on Pendle Water for 7 to 44 days yielded evidence of acute toxicity on 3 of the 4 occasions a storm event occurred during the deployments. On the River Trent, four storm sewage discharge events during the three deployments of 33 to 44 days did not have a significant lethal effect on either caged *G. pulex* or caged fish.

8.4.1.2 Biosurvey Techniques

The use of biosurveys for event analysis is obviously more difficult and requires regular surveying to gain an insight into the impact of particular events, especially if these occur in isolation. Otherwise, biosurveys are most appropriate for assessing multiple events or long-term analysis. A series of biosurveys is generally needed at a location so that seasonal effects on community abundance and diversity can be accounted for in the analysis.

At KLSS, long-term impact has been assessed by conducting biosurveys at four locations over an 8-month period from October, 1995, to June, 1996 (see Section 8.1.1). Statistical analysis (see Figure 8-1) showed that the invertebrate community was significantly more diverse at US sites, was dramatically impaired at the point where the discharge entered the channel and showed some recovery DS.

During previous studies, the project team has investigated the effects of CSOs at two sites in the United Kingdom: Pendle Water (Lancashire) and the River Trent (Staffordshire) (Milne et al., 1992). The quality of the receiving water was assessed using the BMWP (Biological Monitoring Working Party) and ASPT (Average Score Per Taxon) scores (Armitage et al., 1983). The BMWP score is an index that combines into a single numerical expression both a qualitative or quantitative measure of macroinvertebrate species diversity depending upon the collection procedure and qualitative information on the ecological sensitivities of individual taxa (Metcalfe, 1989). Scores are based on the presence or absence of certain invertebrate families within a sample. The score is obtained by summing the individual scores of all the families present in the sample. Score values (maximum of 10 and minimum of 1) for individual families reflect their pollution tolerance based on a knowledge of distribution and abundance, with pollution intolerant families (such as the Ephemeroptera) having high scores and pollution tolerant families (such as Oligochaeta and Chironomidae) low scores. The average score per taxon (ASPT) is calculated by dividing the BMWP score by the total number of scoring taxa.

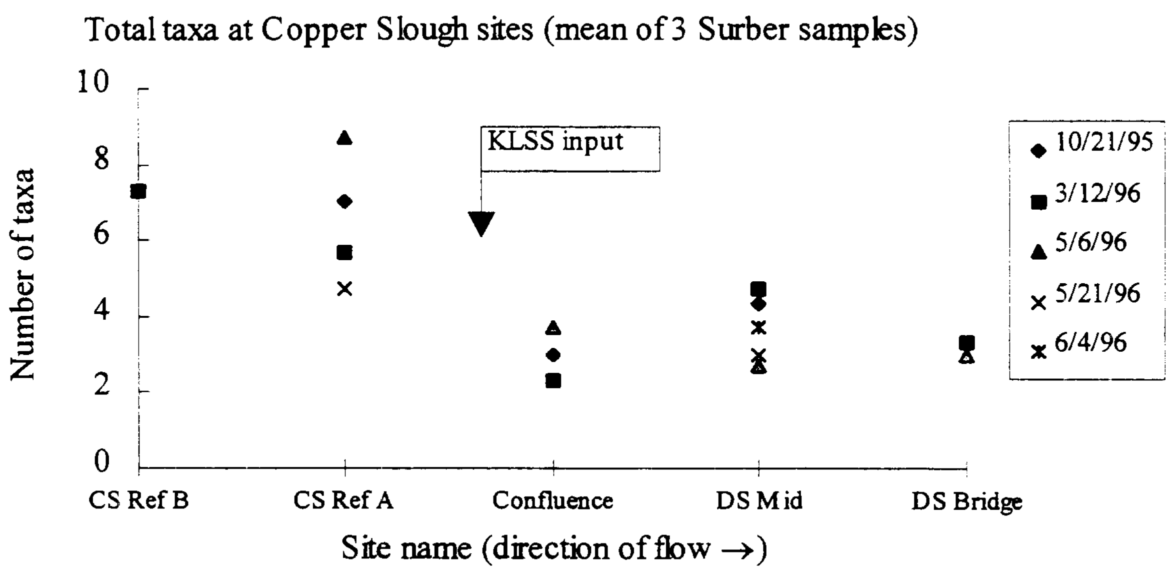


Figure 8-1. Summary of Biosurvey Data for Locations on the Copper Slough

At Pendle Water, sampling of invertebrate communities (by Surber sampler taken on 11 occasions between August, 1988, and July, 1990) indicated that discharges from a CSO exerted a chronic effect on the benthos downstream. However, the impact was limited to a zone of less than 250 m (820 ft) from the discharge. The numerical dominance of oligochaetes contributed to low species diversity downstream of the CSO. In addition, decreased BMWP, ASPT, and diversity were attributed to the absence of certain pollution sensitive species probably as a result of the toxic effect of discharges. Reductions in mean BMWP scores ranged from 2 to 27 when comparing a site 10 m (32.8 ft) upstream of the study CSO to a site 10 m (32.8 ft) downstream, and from 3 to 13 when comparing the upstream site with a site 100 m (328 ft) downstream (on the seven occasions within the study period that samples were taken at this site). Another observation was the reduction in invertebrate population densities following major storm events, although this trend was also observed at sites upstream and downstream of the CSO. Physical disturbance of the river bed during high flow was considered to be the major factor responsible.

Milne et al. (1992) also studied the River Trent (at Abbey Hulton, Stoke-on-Trent). BMWP, ASPT, and total taxa tended to be higher at sites upstream of a CSO. Reductions in mean BMWP scores (from samples taken on five occasions between August, 1991, to January, 1992) ranged from 14 to 27 when comparing downstream and upstream sites. High densities of oligochaetes found 200 m downstream from the CSO discharge suggested that the CSO discharges were causing chronic organic pollution. Tentative evidence of an acute impact was provided by the large reduction in mean densities of Baetidae (mayfly) downstream from a CSO following one storm event.

Whiting and Clifford (1983) investigated the impact of urban runoff in a small Canadian stream (Whitemud Creek) within Edmonton, Alberta. Seven sampling stations were used to assess the impact of six storm sewer overflows and samples were collected from each site at approximately 3-week intervals from April, 1976, to May, 1977. A number of invertebrate species common to a site upstream of the urban area were absent or rare within the city where oligochaetes and chironomids were very abundant. Species diversity calculated using the Simpson index (Simpson, 1949) and richness (number of taxa) were much lower downstream within the city than upstream. The changes in the urban invertebrate fauna were attributed to the discharge of organic materials and silt from storm sewer overflows. The magnitude of the effects of storm sewer runoff appeared to have been directly related to the area drained. Large faunal changes were found below the outlet of the second storm sewer system that drained 10.4 km^2 (2,570 acres), whereas little change was found below the third outfall discharge which drained 0.6 km^2 (148 acres).

Hoffman and Meighan (1984) studied the impact of a series of CSOs from San Francisco on various sites on the western shore of central San Francisco Bay. The study monitored the effects of three storm events between February and March, 1979, at 16 stations. Replicate benthic infauna samples were obtained using a 0.05-m^2 (0.538-ft^2) Ponar grab sample. Species diversity was calculated by the Shannon-Weiner index. A fisheries survey was also carried at six stations, 8 days after the end of the third overflow event using a 7.6-m (25-ft) otter trawl. The benthic infauna did not indicate any definitive decrease in the number of species or individuals per station as a result of any single overflow event. Species diversity was highest at those stations beyond the immediate degradation zone from the CSOs. Increased species diversity and biomass were considered to reflect the availability of food with increased organics in the sediments and increased suspended organic materials from the CSOs. Reduced fish abundance and diversity was found at the sites closest to the CSO discharges. This was considered to result from the unsuitability of these locations for most fish species due to the influence of CSOs on the sediment and the paucity of benthic invertebrates. A study of the effects of urban runoff on benthic macroinvertebrate community composition was conducted at eight sites along two branches of Shabakunk Creek (New Jersey) by Garie and McIntosh (1986). Quantitative sampling using a Surber sampler was carried out at six sites on the heavily developed West Branch and two sites on the lightly developed Main Branch during 1979/80. The analysis of the benthic collection was performed by examining changes in taxa richness and population density at the eight sites. Benthic macroinvertebrate samples collected by the multiplate artificial substrate samplers differed markedly in terms of community composition from those obtained by a Surber sampler and were not considered to be representative of those from the stream bed. On the basis of the Surber sampler data, the effects of urban runoff on the benthos of Shabakunk Creek included decreases in taxa richness and population density, along with shifts in community composition. Increased concentrations of heavy metals in the substrate were considered to be a contributory factor.

Pedersen and Perkins (1986) compared the benthic macroinvertebrate community of a Washington State stream in an urbanized watershed (Kelsey Creek) with that in a similar sized stream in a nearby rural location (Bear Creek). Buried colonization chambers containing natural rock substrates (Radford and Hartland-Rowe, 1971) were deployed at three sites on Kelsey Creek and two on Bear Creek. No significant difference existed between the urban and rural stream in terms of the average number of benthic invertebrates that colonized the samplers. However, a substantial difference existed between the composition of the benthos in the streams, such that the rural stream had nearly twice the functional diversity of the urban stream. The benthos of the urban stream was reported to be dominated by a few groups of invertebrates that could adapt to the erosional/depositional nature of the substrate and could utilize transient, low-quality food sources.

8.5 Water Quality Questions

8.5.1 What is the Relationship between Water Quality and Sediment Quality?

Relationships between water quality and sediment quality are complex and poorly understood. Chemically bound contaminants can re-enter the water column through chemical processes, particularly if resuspension occurs during storm flow events. Sediment toxicity is generally a chronic problem and relates to the long-term time scale. Therefore, it is in the context of this time scale that this question may be asked. Use of in situ exposure tests with designs that include and exclude sediment exposure can indicate differences between sediment quality and water quality. However, an insufficient understanding precludes reliable predictions of long-term water quality effects from either a chemical or biological assessment of sediment quality. More research is needed in this area.

A field deployment of caged *Hyalella azteca* was undertaken at the KLSS site with the objective of comparing water column toxicity and sediment toxicity (see Table 8-2). Groups of animals were caged out for 10 days, either in the water column only or with sediment contact. The results showed that the organisms in contact with sediment in the KLSS basin suffered significantly higher mortality than those in the water column at the contaminated site, but there was no significant difference between water- or sediment-related mortality at the reference site.

8.5.2 Where and When Do I Sample Water Quality to Support In Situ Testing?

Water quality analyses can strengthen the establishment of a toxicity cause-effect relationship, if mortality (or another endpoint) can be related to measured contaminant concentrations. It should be recognized, however, that this might not always be feasible where complex mixtures of contaminants are involved; indeed the whole rationale for stormwater toxicity testing rests on the inadequacy of chemical analysis alone as a tool for monitoring stormwater. See also Section 8.1.6.

Table 8-2. Toxicity Data for In Situ *H. azteca* Water Column and Sediment Tests

Location	Lethality (%)	
	Water column	Sediment
CS REF	10	20
KLSS	43	80

Where a particular contaminant is known to be a problem, perhaps from bioaccumulation studies, advanced screening tests, such as TIE (see Section 7.9.8 and Appendix B), might be able to trace the in-stream problem back to source.

To link in situ test results to storm event chemistry, continuous monitoring is clearly the most appropriate methodology, coupled with automatic samplers for parameters that cannot be continuously monitored. Ideally, monitoring points should be at, or in the vicinity of, the in situ testing site.

8.6 Test System/Assessment Procedure Questions

8.6.1 What Is the Best In Situ Test System?

The best in situ test system for a particular program is determined by the program objectives and the application of the test system selection methodology. The selection of test systems is based on time-scale considerations and the performance of the test against time-scale-specific criteria. Of the three time scales identified (intra-event, event and long-term), in situ tests systems are relevant to the event and long-term time scales. Where the time scale of interest is event, tests with relatively shorter induction times are most appropriate, for example lethality-based tests and feeding rate tests. For the long-term time scale (multiple event), these event-time-scale tests might still be applicable when deployed in a rolling program, as well as tests with relatively longer induction times, such as bioaccumulation tests and colonization.

8.6.2 What Is the Best Biosurvey Procedure?

As discussed above, the selection of test systems is based on time-scale considerations. Biosurveys are fairly exclusively directed at long-term time-scale assessments though they might be relevant in the event time scale (see Section 8.4.1). As such, time scale is not the major factor in assessing which biosurvey procedure is best for a particular program. Relevant considerations include:

- Which procedure will be most cost-effective and provide the most relevant information to meet study objectives?
- What organisms are present in the system and which are most appropriate? (see Section 8.2.4).
- Have any biosurveys been done previously (continuity will allow comparison with historic data)?

The RBPs developed by US EPA include three protocols for benthic invertebrates and two for fish. The appropriate biosurvey procedure depends on the study objectives. Benthic RBP I and Fish RBP IV are screening tools to help determine if biological impairment exists. Benthic RBPs II and

III and Fish RBP V are more rigorous and provide more objective and reproducible evaluations than RBPs I and IV. RBPs II, III, and V are semiquantitative and use an integrated analysis technique to provide continuity in evaluation impairment among sites and seasons. Each of the RBPs is summarized briefly in the following subsections.

8.6.2.1 Rapid Bioassessment Protocol I—Benthic Macroinvertebrates and Rapid Bioassessment Protocol IV—Fish

These RBPs are screening mechanisms to identify biological impairment. They are not intended to determine the degree of impairment nor provide definitive data to establish cause-and-effect relationships. They allow a cursory assessment, using cost and time efficiencies to evaluate a large number of sites, identify major water quality problems, and help plan and develop management strategies.

8.6.2.2 Rapid Bioassessment Protocol II—Benthic Macroinvertebrates

This RBP provides information to rank sites as severely or moderately impaired so that additional study or regulatory/management action can be planned. Like RBP I, this protocol can be used as a screening tool and allows agencies to evaluate a large number of sites with relatively little time and effort. The more documented procedures and integrated metrics of RBP II promotes better consistency and allows better comparison among sites.

8.6.2.3 Rapid Bioassessment Protocol III—Benthic Macroinvertebrates and Rapid Bioassessment Protocol V—Fish

These two RBPs provide a consistent, well-documented biological assessment. Like RBP II, they provide information for ranking site impairment and a way to compare repeatable results over time (trend monitoring). These RBPs include taxonomic identifications to the lowest practical level, thereby providing information on population, as well as community-level, effects. They include an integrated assessment of metrics and can be used to develop biocriteria.

8.6.3 Do I Use Different Tests in Different Regions?

The same categories of test systems are appropriate for all regions, although in some cases there may be seasonal constraints. What might differ between regions is the organisms used (see Sections 8.6.4 and 8.6.5).

8.6.4 Should I Use Indigenous Organisms as a Test System?

There are a number of arguments for and against using indigenous organisms (i.e., collected within the study system) for in situ tests, as opposed to using laboratory stock organisms. Using indigenous organisms gives a site-specific element to the testing program. It might also avoid problems of lack of tolerance to site-specific conditions (see below), and avoids any risk of the undesirable, or unlawful, release of nonindigenous species or strains. On the other hand, sensitive organisms might be absent due to previous exposure to contaminants, and it is often difficult to collect organisms of the desired age and condition.

The use of laboratory stock organisms has the advantage that standard species have known responses and tolerances to contaminants, and a large body of published information is available to aid in the interpretation of results. Additionally, quality assurance/quality control (QA/QC) procedures, such as stock sensitivity control, can be undertaken more effectively. Availability is another factor that influences the decision about which organisms to use.

8.6.5 What Must I Do to Successfully Deploy Common Laboratory Species, such as *Ceriodaphnia*, *Hyalella*, etc., in In Situ Test Systems?

To deploy laboratory species, a reliable source of organisms is required. If no local supplier can meet the requirements, a culture must be established and maintained. The other major requirement is equipment, mainly suitable cages (see Section 8.2.3).

To deploy caged laboratory stock species, the receiving water background physicochemical characteristics (such as pH, hardness, temperature, and dissolved oxygen) must meet requirements for their survival.

8.6.6 Are There Special Procedures—Water Quality or Toxicity Analyses—Supporting Certain Test Systems?

The extent of phototoxicity due to PAHs can be investigated by deploying test organisms with (in the sun) and without (in the shade) ultraviolet light. Ireland, Burton, and Hess. (1996) found a definite increase in mortality of *C. dubia* that were in contact with PAHs in the Little Scisto River and exposed to UV radiation.

Table 8-3 shows the results of deployments of *H. azteca* and *P. promelas* in the sun and shade at the CS-REF and KLSS basin sites. A degree of lethality measured at the *H. azteca* in situ test might have been due to the photo-induced toxicity caused by the presence of PAHs.

Table 8-3. Toxicity Measured in *H. azteca* and *P. promelas* In Situ Tests Located in the Sun and Shade

Location	Lethality in *H. azteca* in situ test (%)		Lethality in *P. promelas* in situ test (%)	
	Sun	Shade	Sun	Shade
CS REF	30.0	15.0	16.7	10
KLSS	46.7	26.7	6.7	10

8.7 Interpretation and Analysis Questions

8.7.1 What Does an In Situ Test Mortality Really Mean?

If mortality is observed at an impacted site following wet weather events, the first and most important thing to do is to ascertain that the observed mortality is significantly greater than mortality observed at the reference site, using appropriate statistical techniques. If there is no statistical difference, then no effect can be ascribed to the wet weather input under investigation. If there is a statistical difference, the observed mortality might be due to wet weather events. To aid in the interpretation of in situ mortality data, look to see if the mortality ties in with the findings of any biosurveys or laboratory biological test analyses.

8.7.2 How Should I Analyze Field Data? Must I Identify Species? Which Water Quality Index is Appropriate for Wet Weather Event of BMP Effect Analysis?

The analytical methods for field data should be established as a part of the initial study design. The study design includes specification of the type of data to be collected, either structural or functional data, or both. Measurements of structure focus on the numbers and kinds of organisms. Measurements of function focus on what organisms do.

The relationships between structure and function can be illustrated by what happens when a community is subjected to a contaminant—placed under stress. When a stress is imposed, a threshold in response is reached. Initial changes can result in species acclimation to the increased stress, producing changes in function but not structure. If stress is increased, more sensitive species are lost and replaced by more tolerant species; this transition is reflected by a corresponding change in structure but not necessarily function. Further stress affects even tolerant species so that with elimination of organisms, function is lost as well. The changes in structure and function can be modified by the initial stress level. An acute stress, one of high magnitude but short duration, can lead directly to the loss of structure and function. Therefore, field data should be analyzed in terms of both structure and function.

8.7.2.1 Structure

The analysis of structure requires identification of the organisms present. The first step in biosurvey data analysis occurs during study design. Study objectives define the taxonomic sophistication required for organism identification along with specification of data analysis methods or indices. Guidance for data analysis is provided in many sources; the analytical procedures accompanying RBP protocols provide a useful starting point for field data analysis of macroinvertebrate and fish data. The major caution in analysis is that most analytical procedures are designed for constant stress levels and might be inappropriate for time-scale analyses needed in wet weather discharge analysis. This is particularly true for condition and state indices (e.g., Ephemoptera-Plecoptera-Trichoptera (EPT) index; application of scraper/filtering collector or shredder to total taxa ratios; or application of biotic or community similarity indices) that have not been adapted to address specific time-scale issues.

A general rule of thumb is that more accurate identification of species present allows more complete and complex analytical procedures. Species level identifications are a basis for accurate community description and also provide a foundation for detailed identification and/or analysis of environmental factors that might be critical to the species, such as data on life history or other autecological requirements. Species identifications are not needed in all cases, but species identifications provide the best information to any assessment. RBP protocols offer good guidance for selection of taxonomic discrimination needed in the analysis of field data.

A fundamental property of an index is that it selects characteristics from a data set to summarize in the index value. In this summarization process, significant information may be lost or underutilized in field data analysis. The most common water quality indices (e.g., Hilsenhoff Index or the Index of Biotic Integrity—IBI) have been developed to provide only a general assessment of aquatic community state or condition. No indices specific to wet weather conditions are widely used.

In summary, the analytical procedures for biosurvey data should be established as part of the study design and meet all requirements of a quality assurance program. Analysis can be simple or complex depending on objectives and analysis criteria. Taxonomic sophistication in data analysis can also vary from identification of macroinvertebrates to order to confirmed species identifications. The level of discrimination in taxonomy is be set by analysis objectives. To date, no wet weather indices are widely used.

8.7.2.2 Function

The fundamental functional characteristics measured in biosurveys include biomass production (ecological energetics), trophic or systems regulation, and nutrient cycling. The most promising measures of these functional characteristics include:

- Changes in primary productivity/respiration;
- Changes in energy flow;
- Changes in decomposition;
- Changes in material cycling; and
- Changes in internal regulatory processes.

The usual focus of analyses for functional measures in biosurveys are listed in the following paragraphs:

Productivity and Respiration. Changing productivity leads to changes in the energy pool available and an alteration in turnover time of carbon/food resources. It is important in this analysis that time constants be carefully selected and correlations between photosynthesis and respiration are carefully developed.

Food Web and Functional Regulation. The regulation of energy and nutrient dynamics involves interactions among producers and consumers in an ecosystem. Measurements of these interactions are made by analysis of:

- Change in numbers of either a producer or a consumer;
- Movement of materials;
- Alteration of the environment; and
- Interactions with other consumers.

Material and Energy Movement. Energy transformation processes are regulated by essential element availability. Common measures include analysis of elemental retention for producers or consumers or analysis of the mobilization of essential elements and the regulation of these elements.

Decomposition and Element Cycles. In the cycling of materials, decomposition is an essential part of natural cycles. Measures of leaching, faunal breakdown, and microbial mineralization are typically performed to assess decomposition. The regulation of decomposition is of some importance. The factors that directly regulate decomposition include the physicochemical environment, available resource quality and quantity. Common measures include:

- litter accumulation and decomposition;
- Leaching, i.e., materials lost and rate;
- Nutrient export; and
- Nutrient and mineral cycling (emphasis active accumulation and storage).

Regulation Processes. A general measure often selected for functional measurement includes one or more of the above analyses, emphasizing the assessment of energy flow or nutrient cycling to generate some measure of "power" or the total energy movement through the ecosystem per unit of biomass. A number of <u>metabolic indices</u>, included in this category, have been proposed that respond to perturbation and are related to maximization of persistent biomass. Another measure is the frequency of response in analysis of some periodic character (including metabolism, biomass, and/or nutrient stability). This is often measured in terms of a <u>cycling index</u> or <u>path length</u>, and is typically based on the number of compartments present in the system. It might include quantification of processes, such as nutrient cycling.

8.7.3 How Do I Conduct Sample-Specific Analyses? (What Information Should I Extract from a Sample?)

The analysis of biosurvey results can be segregated into sample-specific analyses and comparative analysis between samples. A range of techniques are available for sample-specific analysis for both structural and functional data, with an emphasis on structural data analysis. The starting point is the definition of sample elements (e.g., organism identification). This identification can range from discrimination at the taxonomic level of an order to complete species identification. Selection of discrimination level defines an operational taxonomic unit (OTU). Once an OTU has been defined, then it is possible to identify which characteristics of the sample to measure. The analysis of sample characteristics usually includes:

1) organism specific analyses
   tissue studies (bioaccumulation)
   general health/condition (morphological abnormalities or tumors)
2) enumeration of numbers and kinds of organisms
3) enumeration of abundance and biomass of organisms
4) evaluation of population characteristics for each OTU
   size
   biomass
   trophic status
5) evaluation of community characteristics
   relative abundance of OTUs
   OTU dominance
   sample diversity

The first step is the preparation of a species or taxonomic listing. Then, counts will generally be made of the numbers of individuals in any OTU. It is the species list with individual abundances that provides the basic data for further analysis. In single samples, analysis will develop:

- The total number of species or OTUs;
- The total number of individuals (standing crop);
- A rank abundance tabulation;
- Frequency distribution.

It is now possible to relate the sample data to species-specific information, such as species autecology, niche analysis, trophic organization, OTU guild placement, pollution tolerance, etc. Once this information has been extracted from the data, it is possible to perform calculations on single samples using various indices:

- Pollution Indices— Pollution indices are generally developed based on some assessment of relative tolerance of certain species, using that information to assess pollution consequence.

- Diversity Indices—The most common indices used are diversity indices. A diversity index uses numbers of species and relative abundance to calculate a measure of diversity. The general assumption is that a more diverse community will be healthier.
- Biotic Indices—Based on concepts of integrity or a particular view of ecosystem organization or function, these indices are based on biotic characteristics. They can include ecological indices, such as niche overlap, interspecific association, and interspecific covariation. These indices usually require quantitative measures of species abundance.

8.7.4 How Do I Compare Samples from Different Sites or Different Times?

To compare in situ test or biosurvey data from a different locations on a watershed, it is necessary to incorporate a general or background control that is considered to be free from anthropogenic inputs. The values generated at this site can then be used to identify whether the extent of impact at study sites and local reference sites.

All of the information developed in single sample analysis can be compared between sites or through time. Typical sample comparison methods include correspondence or resemblance matrix calculation that allows clustering or ordinations and various multivariate analysis techniques.

8.7.4.1 Differences or Similarity

The identification of similarity (or difference) between samples is accomplished using either species lists (presence/absence or binary data) or abundance tabulations (quantitative data). Coefficients of similarity are available for either binary or quantitative data and selection of a similarity measure depends on the nature of the data, particularly the general correspondence of the species lists.

8.7.4.2 Binary Data

The most commonly used binary data, similarity analysis method is the use of the Jaccard coefficient. It can be used to discriminate between closely similar samples. It provides a direct comparison of species lists unbiased by species numbers but biased by the presence of rare species. Other coefficients of similarity identified include Kulezynski, Sorensen, and Mountford coefficients.

8.7.4.3 Quantitative Data

Coefficients of similarity based on binary data take no account of the relative abundances of the species at each station and tend to overestimate the importance of rare species and underestimate the importance of common species. This can be avoided by the use of coefficients that compare not only species lists but also the relative contribution made by each species. Some quantitative methods are biased by the numbers of individuals in a sample, so data transformations may be necessary.

Common quantitative similarity coefficients are derivatives of distance measures, such as the Bray-Curtis coefficient and distance coefficient. The Bray-Curtis index ranges from 0 (no species in common) to 1 (identical samples). The use of a geometric model to represent the relationship between species lists (communities) is accomplished in calculating distance coefficients. As an example, a comparison of two communities each with three species can be accomplished by representation in a three-dimensional space with the distance between positions in the three dimensions a measure of similarity.

Pedersen and Perking (1986) compared the benthic macroinvertebrate community of a Washington State stream in an urbanized watershed (Kelsey Creek) with that in a similarly sized stream in a nearby rural location (Bear Creek). The Canberra Metric index (Clifforde and Stephenson, 1975) produced groupings of sites on the urban and rural streams which were consistent with other measured data.

8.7.4.4 Cluster Analysis and Ordination

When community structure data are analyzed beyond simple similarity or correlation analysis, the influence of many variables can take a significant role in associations between samples. Green (1979) has reviewed multivariate approaches in the assessment of ecological similarity and identified two broad categories of multivariate analysis that are based on the similarity or resemblance matrices produced when a number of samples are analyzed. These two categories include cluster analysis and ordination. Both procedures allow visual interpretation of sample relationships and can be combined to increase analytical capabilities.

Cluster analysis associates in a dendrogram those samples which are most similar (or dissimilar) and provides a visual display of sample associations. A number of clustering techniques and procedures are available for both binary and quantitative data (used to calculate coefficients of similarity to generate the resemblance of dissimilarity matrix). Because the dendrogram provides a two-dimensional display of complex resemblance patterns measures of accuracy of the display are often presented with the dendrogram. A widely used indicator of display accuracy is the coephenetic correlation coefficient.

Cluster analysis allows discrimination of associations between samples while ordination techniques are often applied to identify possible causes for observed associations. Ordination assumes a relationship between species abundances and various environmental factors. Samples are separated or associated on one or more axes that are interpreted with knowledge of known environmental conditions. Other techniques, such as principal component analysis, factor analysis, principal coordinates, canonical correlation, and multidimensional scaling, provide additional multivariate analysis techniques.

8.7.4.5 Rank Comparisons and Correlations

Community comparisons can also be made using species ranks. Spearman's rank correlation coefficient and Kendall's coefficient have both been widely used. The major drawbacks of these methods are the presence of rank ties that reduce comparative strength and species absence that requires decisions on placement in the ranking list or exclusion from comparison. Correlation coefficients based on probabilistic models can be calculated from either binary or quantitative data. The point correlation coefficient and product-moment correlation are both useful correlation indices.

8.7.5 What Do I Do if In Situ Tests Disagree with Laboratory Testing Results?

The results from in situ tests might disagree with laboratory tests results due to the different exposure conditions experienced by the organisms under the two scenarios. Laboratory tests on sediment samples and in situ deployments with *D. magna* and *H. azteca* were carried out for the 6/1/96 storm at the KLSS system, and for both species, lethality was generally lower in the laboratory test rather than the in situ test (see Table 8-4). This finding is consistent with a study by Jacher and Burton (1993), who found that toxicity in *H. azteca* tests conducted in situ at agricultural and urban sites was greater than that measured in laboratory assays. The differences in lethality between laboratory and in situ tests might have been due to differences in flow rate, temperature, or higher dissolved oxygen levels in the laboratory than were typical of field exposures. Chemical partitioning of toxicants in the water at the site and consequently the continuous exposure of organisms to contaminants at this site could also cause a difference in response when compared to the laboratory test conditions in which uncontaminated, overlying water was used and renewed daily.

Table 8-4. Toxicity Data from Laboratory and In Situ Sediment Tests Using *D. magna* and *H. azteca*

Location	Lethality in *D. magna* tests (%)		Lethality in *H. azteca* tests (%)	
	Laboratory	In situ	Laboratory	In situ
CS REF	23	20	10	27
KLSS	63	100	53	83

In such cases where there are conflicting laboratory and field results, examination of both field and laboratory procedures, exposure conditions, and other location- and event-specific factors are needed. Field tests are less artificial than laboratory tests, although generally at the cost of less rigorously controlled conditions. Therefore, field test results should be considered to be a more reliable indicator of actual receiving system impact, while laboratory testing should be considered a more reliable indicator of toxic potential. Clearly, judgment will involve consideration of the degree of discrepancy between tests and possible reasons for observed differences.

CHAPTER 9.0

CONCLUSIONS

This project has involved analysis, laboratory studies, and field assessments. An extensive research record has been developed and is available in annual reporting, interim reports, and publications. The major conclusions of this research project, relating to each of the project objectives, are presented in the sections that follow.

Objective #1—Develop a database for frequency and duration of exposure for contaminants in CSO and stormwater runoff.

This research quantified the frequency of wet weather events at regional study sites, identified the presence of toxic contaminants in storm event samples, analyzed mechanisms that lead to the exposure of aquatic organisms to wet weather contaminants, and developed, from literature sources and field data, information on contaminant presence, exposure duration, and changes in frequency of exposure in wet weather discharges that are region, watershed location, or site specific.
This research also developed a conceptual model that quantifies relationships between chemical toxicity and the frequency and duration of exposure as defined by the hydrologic characteristics of storm events.

From this research, the following conclusions were reached:

- The description of the wet weather hydrograph is an essential first step in defining time scales for toxicity determination.

- It is essential to have a measure of hydrograph response in parallel with any toxicity assessment of stormwater.

- It was possible to develop a simple classification scheme for wet weather flow hydrographs and use this scheme to predict aspects of contaminant loading or exposure.

- Hydrograph peak values, stage duration, and frequency can all be used to predict aspects of contaminant loading or exposure.

- Contaminant concentrations present during wet weather events follow predicted patterns of a first flush high concentration, followed by lower concentrations later in an event due to dilution from rainfall/runoff.

- Variations on this contaminant concentration pattern are common, with a second peak occurring near the hydrograph peak.

- Other peaks in contaminant concentration might be related to first flushes of material from more distant points in the watershed or collection system with longer times of travel.

- Hydrograph and contaminant exposure conditions were comparable in the U.S. and Europe, although site-specific conditions determined actual contaminant presence and exposure conditions.

- Sediment contributions to time-scale toxicity are important, both in short-term exposure conditions associated with sediment resuspension and long-term exposure conditions associated with field sites.

- A simple conceptual model has been developed that defines hydrograph characteristics and calculates toxicity units from contaminant concentration data, providing a predictive tool for impact assessment.

Objective #2—Conduct a comprehensive review of the literature to identify biological test systems appropriate for detecting acute, chronic, and ecosystem effects caused by wet weather events.

In addition to an evaluation of available test systems, a comprehensive review of the literature dealing with the effects of episodic exposure on receiving system biota and ecosystems was completed as a part of this research.

From this review the following conclusions were reached:

- No test systems have been developed specifically for wet weather discharge monitoring.

- To assess the effects of wet weather events, it is necessary to move away from the organism-based approach used for continuous discharges to a "time scale of response" approach, which more realistically represents the intermittent exposure to contaminants with fluctuating concentrations. This means the time-scale characteristics of response, independent of the organism producing that response, is the major criterion for selecting test procedures and test systems.

- It is possible to identify criteria for the selection of test systems that will adequately assess the time-scale toxicity associated with wet weather discharges. Three time scales have been identified (intra-event, event, and long term), based on analysis of a database of frequency and duration of water quality changes developed from literature analysis of time-related contaminant change in wet weather events. These different time scales require different test criteria.

- An objective, criteria-based selection procedure has been developed to identify test systems that meet specific regional or other needs for testing to assess the effects of wet weather discharges on receiving system biota and ecosystems. The selection procedure evaluates test methods against criteria grouped into four main categories: time-scale criteria, measurement criteria, ecological relevance, and cost.

- No single test system adequately met all the criteria required for wet-weather event assessment.

- Modifications to standard toxicity testing methodologies have been developed as a part of this research, to produce new test systems that are more appropriate to wet-weather event time-scale toxicity assessment.

- The time-scale toxicity testing procedure developed as a part of this research accounts for post-exposure response of organisms to short duration exposures to contaminants.

- To meet criteria for a given time scale of exposure, a battery of tests is needed that provides complementary information in a cost-effective manner. For intra-event analysis, a test battery of Microtox, *C.dubia* or *H.azteca* IQ and *C. dubia* or *H. azteca*, and *P. promelas* time-scale lethality tests has been used to assess in-pipe or receiving system-single discharge toxicity. Standard WET tests using *C.dubia* and *H.azteca* are proposed for assessing whole-event toxicity.

- A tiered assessment system should be adopted for wet weather events, in which basic screening is carried out to establish the presence or absence of toxicity in discharges and allow a classification by degree of toxicity. Advanced screening can then be used to identify sources, characterize event toxicity, and define effect characteristics to guide both short- and long-term assessments of receiving water impact. Based on the results of basic and advanced screening tests, analysis can continue to a confirmatory tier that determines or confirms actual effects in the receiving water ecosystem. A key element of assessing the effects of wet weather events is relating the responses measured in samples taken in-pipe to impacts in the receiving water (using in situ tests and biosurveys). Further analysis can focus on long-term monitoring programs to identify the presence of any low level or cumulative effects on the receiving water ecosystem.

Objective #3—Conduct a series of field studies to quantify the relationships between chemical toxicity and the frequency and duration of exposure of aquatic organisms to contaminants in wet weather discharges.

Field study sites near Champaign, Illinois, in Fort Worth, Texas, and in Cleveland, Ohio were used in this research. The primary study site was the Copper Slough watershed, Champaign, Illinois, where comprehensive test batteries were used for storm event toxicity analysis, in situ testing, and biosurveys. Storm event toxicity analysis and limited in situ testing were completed at Fort Worth, Texas, while only storm event toxicity analysis was completed for Cleveland, Ohio. In addition to the field studies, an extensive laboratory testing program was implemented to assess time-scale toxicity. The following conclusions can be drawn from this research:

- Application of test systems to study sites revealed time-scale toxicity of varying degrees, depending on site characteristics and the nature of the storm hydrograph.

- An important adjunct to the determination of time-scale toxicity is the availability of continuous monitoring data for key water quality parameters. The availability of this information helps place samples taken in both an antecedent condition and a storm event context, provide data to focus costly analytical activities on critical samples, and key sampling to water quality transients. It is also important to evaluate toxicity data with regard to chemical monitoring data so that issues such as bioavailability can be considered.

- Discharges from a number of locations consistently showed moderate or high in-pipe toxicity, as measured with a battery of screening tests. However, the in-pipe toxicity did not always result in impact in the receiving water as measured by in situ tests or biosurveys due to the nature of the dilution of storm discharges in the receiving water. This was evident in data obtained from sampling downstream locations in the Copper Slough which indicated infrequent toxicity.

- The tests used to assess wet weather events need to be appropriate to the time scale of exposure likely to be experienced by receiving water organisms. The laboratory-focused research in this project has shown that even short-term exposure (< 1 h) to stormwater discharges can result in post-exposure toxicity even after baseline conditions have been restored.

- The changes in toxicity during the first flush of an event can occur rapidly and the sampling strategy needs to reflect this if maximum toxicity levels in a storm event are to be detected. This may mean sampling at intervals as short as five minutes or less.

- At the main study site (Kaufman Lake storm sewer) no seasonal differences in toxicity were evident although within a particular seasonal category there were differences in the toxicity of individual storms. The differences in storm toxicity during a season were due to such factors as the length of the antecedent dry period, the intensity of rainfall, changes in the nature and deposition of materials on urban surfaces, or the use of chemicals on residential or farm land, as well as receiving water characteristics. Consequently it is important to assess the toxicity of a number of storms. This is needed to evaluate the cumulative impact at a particular location and identify what watershed characteristics influence wet weather event discharge toxicity.

- At a single location, a sequence of storm events can produce varying levels of toxicity. Depending on antecedent rainfall, an initial event, which showed moderate or high toxicity, might be followed by events with low levels of toxicity. The observation of high levels of toxicity in samples from sequential storm events reflects source characteristics.

- The data obtained from different locations on the Trinity River watershed (Fort Worth, Texas) showed differences in toxicity of discharges depending on the location in the watershed and the nature of the inputs. The order of toxicity (highest to lowest) in basic screening tests was industrial > residential > agricultural, which is consistent with findings for contaminant loadings in other studies.

- The regional testing indicated that there were no fundamental differences in the characteristics of the toxic response to wet weather events that could be attributed to specific regional characteristics. The differences in toxicity appeared to be source- and site-specific and generally tracked a response pattern that identified both first flush and later responses.

- The toxic response later in events was related to samples with high levels of suspended solids. The observed toxicity is sometimes attributable to resuspension of contaminants. To this end, any assessment of the impact of wet weather events on receiving water organisms needs to consider the effects resulting from both the water column and the sediment. In general, regional differences in toxicity are probably not of major concern, although adjustment of test procedures to accommodate regional differences in hydrology is needed.

- In situ testing using caged organisms in the Copper Slough watershed produced variable results. Exposure at in pipe, or near source locations produced a toxic response, exposure at downstream locations did not indicate toxicity.

- Analysis of macroinvertebrate communities in the Copper Slough watershed indicated little short-term response to single events although macroinvertebrates did reflect the effects of identified sources of contaminants.

- Laboratory studies, in support of field analyses, resulted in the development of improved methods of time-scale toxicity analysis for time-sequenced samples taken from storm events.

- Regional evaluation of these laboratory test procedures using different water sources and stocks of organisms revealed consistent patterns of response although absolute values of toxicity varied.

- An event toxicity unit (ETU) has been developed from time-scale toxicity testing that accommodates variable exposure conditions during a storm event.

Objective #4—Develop a management context for wet weather discharges that integrates the need for both regulatory criteria and the protection of ecosystem health.

Although mainly focused on event-related time scales, this research did consider impact issues that involve longer time scales important in watershed/ecosystem assessments. Project activities included integration of event-related time scales with receiving system impact assessments. In these impact assessments, a range of issues must be addressed that consider new regulatory approaches (sediment criteria and biocriteria). This research evaluated time-scale effects of toxicants, linking source identification, physical effects assessments, and the identification of biological effects to link region or watershed conditions with magnitude, duration, and frequency metrics of wet weather events. Although no measures of ecological consequence are specifically recommended that integrate the response of ecosystem-level properties and processes with environmental variability and contaminant exposure, a new analysis paradigm was proposed.

When weighing management of wet weather discharges, the following are important considerations:

- The assessment, monitoring, and management of wet weather events must be carried out in a framework that considers the time scale of exposure relevant to the system under investigation (for example intra-event, event, or long-term). Establishing the time scale of exposure requires a careful analysis of location, storm characteristics, sampling needs, and receiving water issues. In particular, the available information on the hydrology of storm events at a location should be assessed to define the sampling regime to be adopted.

- The protocol for wet weather event assessment developed under this project provides a framework for wet weather event assessment and monitoring with a specific focus on storm event analysis and represents a starting point for the development of a management framework. The protocol is designed to be an integral part of the US EPA Watershed Protection Approach and WERF's Framework for a Watershed Management Program.

- A number of uncertainties must be resolved before it will be possible to develop a definitive ecosystem management context for wet weather events.

CHAPTER 10.0

FUTURE RESEARCH

The project team has explored a range of issues associated with time-scale toxicity and regional analysis of impacts from wet weather discharges. A number of research needs were identified during the conduct of this project, and several were addressed as part of the research effort. What can be summarized from the extensive literature review, laboratory, and field studies is that the special needs of wet weather discharge impact assessment are only now being defined in the context of time-scale toxicity, and research is needed in both fundamental and applied areas.

In fundamental areas, the effects of brief exposure to organisms, populations, and communities of organisms are poorly understood. This lack of understanding includes the identification of fundamental processes operating in the receiving system (e.g., transport, mobilization, transformation) and organisms (e.g., contaminant uptake/depuration, transformations and metabolic byproducts, detoxication), as well as the potential response spectra of exposed organisms or systems. In terms of fundamental processes in receiving systems, specific attention should be paid to contaminated sediments, mechanisms of contamination during storm events, and possibilities of resuspension of concentrated contaminants. In time-scale toxicity analysis, the effects of physical stress on organisms, or the effect of unstable habitat conditions are poorly defined. Of particular importance is the development of better predictive tools that will relate channel condition and stability to changing land use and hydrology, particularly when hydrology can be altered by detention-based best management practices. There has also been limited definition of the relationships between time scales of exposure in wet weather events as defined by hydrologic characteristics of the watershed, and relating specific contaminant concentration to land use and/or management practices intended to protect water quality. Of particular importance in the assessment of time-scale toxicity in relation to hydrology is the consequence to both organisms and their habitat of changing frequency of events of different magnitude or duration as land use changes and management practices are implemented.

The exploration of fundamental processes operating in organisms, populations, and communities is an extremely fertile area of research in time-scale issues. A primary element of time-scale toxicity determination is the availability of reference data to allow comparison with data from new research. Reference data can take the form of known responses for common test species, as well as reference properties and processes of communities or ecosystems to judge impact. In terms of common test species, there is extensive research on the response of commonly used test species to continuous exposures, but very little on the response to variable exposure, considering both concentration and frequency. For example, there is little research that adequately addresses the response of commonly used WET testing species to intra-event conditions (e.g., first flush high concentration transients) and multiple event exposure to both high and low concentrations of contaminants. This lack of fundamental understanding of organism response translates to an even greater gap in our understanding of community/ecosystem response where time-scale toxicity issues of wet weather events must be integrated with time scales of response of the communities and ecosystems under conditions of both constant and episodic exposure. Therefore, research is needed to address test system responses to variable exposure and exposure frequency of contaminants, monitoring fundamental organism processes, and identifying specific mechanisms of effect. Similarly, research is needed to define specific types of responses to time-scale toxicity in communities and ecosystems, and the development of metrics applicable to wet weather event discharges.

In the applied area, research is needed to translate advances in the fundamental understanding of the physics, chemistry, or biology/ecology of the environment into useful tools to guide management and regulatory programs. Fundamental issues persist in this applied arena, as well. For example, for most best management practices, few data address the effectiveness of contaminant removal through time and under different loading and hydraulic conditions. Because only a few standard measures of time-scale toxicity exist, research is needed to provide the detailed, management-practice-specific methods for impact analysis. Once a reasonable basis is provided for impact analysis, research is needed to validate management practice impact and, most importantly, develop predictive tools/models that will assist in the design of better management practices.

Although this research identified a test battery for time-scale toxicity analysis, additional research is needed to advance test systems testing in management programs. This will provide both specific guidance for selection of test systems and cost-effective methods to meet minimum information requirements for management and regulation.

APPENDIX A

STORM EVENT CHARACTERISTICS

Objective #1 of the research project supported a comprehensive time-scale toxicity analysis by identifying the conditions that lead to organism exposure to contaminants in receiving systems. To meet this objective, the project team developed a database for frequency and duration of exposure for contaminants in combined sewer overflow (CSO) and stormwater runoff. This database considered regional hydrologic characteristics that would assist in defining storm events. A library was assembled to provide information on storm event characteristics, lending a regional perspective on storm event characteristics and supporting analysis of specific studies conducted in various regions. Analyses have been performed on the Kaskaskia River near Champaign, IL; Johnson Creek in the Willamette River Basin at Sycamore, OR; the Cuyahoga River in Independence, OH (representative of Cleveland OH), Ware Creek near Toano, VA (representative of Virginia coastal areas); the Trinity River in Fort Worth, TX; and the Salt River in Phoenix, AZ. At each site the data gathered included the mean time between storms, categorization of storm events, and a hydrograph characterization of typical storm events. The search criteria for acceptable gauging stations included: proximity to the urban area; at least five years of stream flow record data; a data end date after 1980; and a drainage area less than 20 square miles. Because of the lack of suitable gauged streams in some areas, these criteria were modified slightly. The U.S. Geological Survey Daily Values database was provided on CD ROM by EarthInfo, Inc. and was used for the analysis.

Analytical Procedure

For each analysis, data were gathered for the most recent five-year period for which the data are complete. To determine seasonal affects, the data were divided into three-month blocks corresponding to the seasons of spring, summer, fall, and winter. The stream flow data corresponding to each season were then plotted as cartesian coordinates on a hydrograph with the mean daily flow as the ordinate (y-axis) values and the day of the month as the abscissa (x-axis) values.

For the analysis, it was assumed that a peak on the seasonal hydrograph was associated with a storm event that immediately preceded the peak. To determine the mean time between storm events, the abscissa value corresponding to a seasonal peak was subtracted from the value corresponding to the peak that preceded it, correcting the abscissa value for periods that extended past the end of one month into the next. The analysis was continued until the last peak of the season was reached. Because each season was analyzed separately, the first and last storm events of each season were used as the beginning and ending points, respectively, for the analysis. The mean and standard deviation for each data set and for the entire study period were then computed.

The project team found that the peak flow associated with a storm event was a useful criterion for differentiating large, medium, and small storm events. For storm size separation analysis, the relative flow of each urban watershed was examined separately. The storm size separation criteria were different for each watershed. This reduces comparability between watersheds, but is a useful tool in analyzing storm frequency within a watershed over the five-year period. The stream flow data were analyzed by year to determine the annual number of each type of storm event.

Hydrograph Characterization

A representative storm from each category was selected, based on peak flow and a relatively smooth return to base flow conditions. Following procedures outlined by Linsley, Kohler, and Paulus (1975), the representative hydrographs were analyzed to determine coefficients for the recession curves, as shown in Figure A-1. The shape of the rising limb of the hydrograph is influenced mainly by the character (duration, intensity, etc.) of the storm which caused the rise (Linsley, Kohler, and Paulus, 1975). The character of the storm events in this analysis is not known, due to the nature of the data available. Mean daily flow values do not supply enough information to accurately characterize the rising limb of the hydrograph. However, these data are sufficient to calculate recession constants for the various segments of the recession curve. The general equation for a recession curve is (Linsley, Kohler, and Paulus, 1975):

$$q_t = q_0 K_r^{\,t} \qquad \text{(A-1)}$$

where:

q_t	=	flow at time t units after time zero
q_0	=	flow at time zero
K_r	=	recession constant
t	=	time units after time zero (usually in 24-hour increments)

R0025576

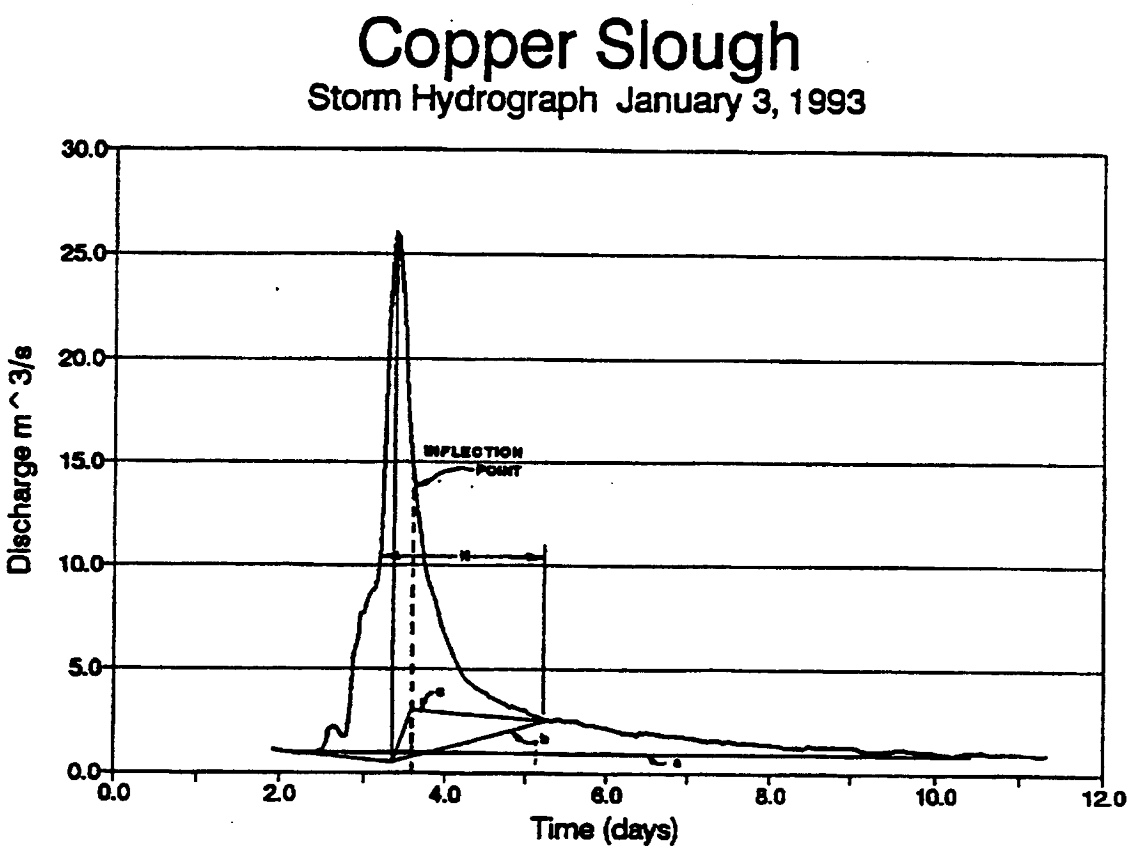


Figure A-1. Example Hydrograph from the Copper Slough, Champaign, IL, Providing an Illustration of Hydrograph Analysis for Base Flow Separation

If, in fact, the recession constant is constant throughout the recession curve, recession data can be plotted on a semilogarithmic graph as a straight line. The slope of this line corresponds to the value of K_r. However, normal recession curves include flow from three types of storage: stream channels, surface soil, and groundwater. Flow from each of these types of storage has different lag characteristics associated with the physical structure of the storage type. Actual data plotted on a semilogarithmic plot can be approximated by three straight lines corresponding to flow from the three types of storage (Barnes, 1940). The transition point between each type of flow is gradual, and graphical techniques are required to determine the recession constants for each section of the curve (Linsley, Kohler, and Paulus, 1975). These three recession constants correspond to base flow, interflow, and runoff.

Hydrologic Analysis Results

Champaign, Illinois. The gauging station selected for this urban area was Station No. 05590000, located on the Kaskaskia Ditch in the Kaskaskia River Basin at Bondville, Illinois. This gauging station has a natural drainage basin area of 12.4 mi^2 and is at an elevation of 689.89 ft above mean sea level. The Kaskaskia Ditch at Bondville is a second-order stream with land use dominated by agriculture. It is located at 40 degrees 6 minutes 47 seconds North latitude and 88 degrees 20 minutes 55 seconds West longitude. This station is located one mile east of Bondville, 3.8 miles west of Champaign at mile 289. Hydrologic data summaries are presented in Table A-1.

A small storm event would result in a peak flow in the Kaskaskia Ditch that was noticeable above the normal base flow on the hydrograph, but below 20 ft^3/sec. A medium storm event would result in a peak flow of between 20 and 100 ft^3/sec. A large storm event would result in a peak flow that exceeded 100 ft^3/sec. It should be noted that these definitions are based on a graphical interpretation of mean daily flows in the Kaskaskia Ditch and are not standardized for use in other climatic zones. The stream flow data were analyzed by year to determine the annual number of each type of storm event. The results are presented in Table A-2.

Table A-1. Summary of Mean Time Between Storm Events for Kaskaskia Ditch

Year and Parameter	Mean Time Between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1986 Mean	7.00	6.67	7.09	15.80
1986 Standard Deviation	2.48	6.68	5.40	12.46
1987 Mean	4.06	8.50	9.33	7.33
1987 Standard Deviation	2.37	4.03	7.63	6.81
1988 Mean	7.00	5.62	7.80	6.15
1988 Standard Deviation	5.34	4.73	7.39	4.69
1989 Mean	6.92	6.21	14.40	6.15
1989 Standard Deviation	4.91	4.35	20.87	4.69
1990 Mean	6.38	6.77	11.60	5.25
1990 Standard Deviation	4.83	4.51	8.19	4.92
Mean for 5-Year Period	6.06	6.66	9.47	7.24
Standard Deviation for 5-Year Period	4.24	4.93	10.72	7.01

Table A-2. Number of Storm Events by Category and Year for Kaskaskia Ditch

Year	Small	Medium	Large	Total
1986	15 (40.5%)	17 (45.9%)	5 (13.6%)	37
1987	23 (48.9%)	23 (48.9%)	1 (2.2%)	47
1988	31 (72.1%)	10 (23.3%)	2 (4.6%)	43
1989	37 (78.7%)	7 (14.9%)	3 (6.4%)	47
1990	18 (51.4%)	9 (25.7%)	8 (22.9%)	35
Total 1986-1989	124 (59.3%)	66 (31.6%)	19 (9.1%)	209

A representative storm from each category was selected, based on peak flow and a relatively smooth return to base flow conditions. The representative hydrographs were analyzed to determine coefficients for the recession curves. Graphical analysis has been performed on the recession curves for a representative storm event in each size category—small, medium, and large. The representative small storm event occurred in the period January 1 to January 24, 1989. The representative medium storm event occurred in the period July 9 to July 29, 1986. The representative large storm event occurred in the period December 6 to December 31, 1986. The calculated recession constant data presented in Table A-3 are based on a 24-hour time interval.

Table A-3. Recession Coefficients for Storm Events in Kaskaskia Ditch

Storm Event	K_r		
	Base Flow	**Interflow**	**Runoff**
Small	0.93	0.69	0.11
Medium	0.89	0.68	0.45
Large	0.95	0.72	0.33

A second set of hydrologic data was analyzed from Champaign, Illinois for the Copper Slough, an urban stream that was the subject of intensive wet weather event analysis in this project. The hydrologic information used in this analysis was obtained from a stage recording station located approximately 20 m upstream of the confluence of the Copper Slough and the Kaskaskia River and is approximately 5 km west of the Champaign-Urbana city limits. The Copper Slough at the stage recorder was a third-order stream with a drainage area of 41 km^2. Land use in the watershed is approximately 40% urban and 60% agricultural.

Hourly stage data have been recorded for the Copper Slough from June, 1991, through December, 1995. The stage data were converted into discharges using a formula statistically derived from measurements of discharge and depth (Lawler, 1994). Hourly discharges were estimated for the period of October, 1991, through June, 1993. Baseflow for the creek is in the range of 0.5 to 1.0 m^3/sec.

A data set with beginning, peak, and end times of each storm were tabulated, as well as the peak discharge. With these data, it was possible to develop a histogram summarizing hydrograph duration, time between storm events, and the ratio of time to peak and the time of recession of each storm. In addition, baseflow separation techniques were applied to a storm event which occurred on January 3, 1993, to identify the surface and groundwater contribution to the stream hydrograph.

The January 3, 1993, storm event was chosen to demonstrate the three methods of base flow separation: straight line, fixed base, and variable slope. The runoff and base flow volumes were then calculated for each method and these are summarized in Table A-4.

Table A-4. Base Flow and Storm Runoff Volume for January 3, 1993 Storm Using Straight Line, Fixed Base and Variable Slope Methods

Method	Hydrograph Volume (m^3 x 10^6)	Base Flow		Storm Runoff	
		Volume (m^3 x 10^5)	% Total Volume	Volume (m^3 x 10^6)	% Total Volume
Straight Line	2.51	6.46	25.7	1.86	74.3
FixedBase	1.84	3.37	18.3	1.50	81.7
Variable Slope	1.83	5.19	28.4	1.31	71.6

Estimates of the base flow of the storm obtained via the three base flow separation analyses ranged from 18% to 28.4% of the hydrograph volume. The fixed base method tended to truncate the hydrograph and yielded the lowest hydrograph volume of the three methods. Even though the total hydrograph volume of the straight line and the variable slope methods varied by 30%, the percentage of base flow obtained through the methods was fairly consistent. The baseflow volume of 1.83 x 10^6 m^3 computed by the variable slope method is equivalent to a 3.2-cm depth over the watershed.

Hydrographs for the Copper Slough can be divided into small, medium, and large events. From baseflow separation of selected storm events, it was observed that the percentage of hydrograph volume as baseflow decreased as the magnitude of the storm event increased, since there was a limit of the storm runoff that could infiltrate into the groundwater. In this context, the percentage of base flow (28%) from a large event, such as the January 3, 1993, storm, is in agreement with the baseflow percentage of 33% obtained from a similar event on August 12, 1993.

A summary of hydrograph statistics for Copper Slough is shown in Table A-5. For the hydrograph duration and the time between peaks, there was no observable statistical pattern in the data. The histogram for peaks above base, indicated that peak discharge varied inversely with the number of storms. The parameter, time to peak (Tp) divided by recession time (Tr), which relates to the shape of the hydrograph, was evenly distributed between 0.1 and 0.5, indicateing that there is potentially a limiting factor in the shape of the hydrograph given a specific peak or recession time.

This time between peaks was compared to regional rainfall data. The analysis found that 30 of the 106 peaks (28%) were within 1 day of each other (Table A-5). According to rainfall data for the Champaign-Urbana, Illinois area, the mean annual time between rainfall events was 6.2 days (gamma distribution). Given the coefficient of variation for the rainfall data of 1.02, the probability of a storm event within 1 day of another is approximately 20%. This conflict would potentially indicate that a typical runoff event has multiple peaks due to timing of the runoff or that the area distribution pattern of rainfall for the watershed would create several runoff peaks.

Additional analysis was performed for the period from June, 1994, to October, 1994, to relate rainfall to hydrograph characteristics for a sampling station located approximately 2 km upstream from the confluence stage recorder. Level information at this site was obtained from a Datasonde 3 multiparameter monitoring probe fixed to a surveyed elevation in the stream. The length of time from the onset of a storm event to an increase in level varied from approximately 45 min to nearly 4 h, depending on the intensity-time pattern of the rainfall. The time to peak discharge varied less, generally being between 4 h and 4 h 40 min.

Table A-5. Summary of Hydrograph Statistics for Copper Slough for October, 1991, to June, 1993

	Peaks above Base (m^3/Sec)	Duration (Days)	Time Between Peaks (Days)	Ratio Tp/Tr*
# of Observations	110	50	106	50
Mean	2.51	0.92	2.83	0.26
Average	4.26	1.36	5.12	0.33
Standard Deviation	4.51	1.50	6.29	0.23
Maximum	26.1	7.88	37.5	1.20
Minimum	0.73	0.29	0.21	0.05

* Tp = time to peak; Tr = recession time

Portland, Oregon. The gauging station selected for this urban area was Station No. 14211500, located in the Willamette River Basin in Johnson Creek at Sycamore, Oregon. This gauging station has a natural drainage basin area of 26.5 mi^2 and is at an elevation of 228.47 ft above mean sea level. It is located at 45 degrees 28 minutes 40 seconds North latitude and 122 degrees 30 minutes 24 seconds West longitude. This station is located 2.5 mi east of the city limits of Portland at mile 10.2. The stream is 2/3-order with suburban/urban land use. The data chosen for analysis cover the years 1989 to 1993 (Table A-6).

A small storm event would result in a peak flow in Johnson Creek that was noticeable above the normal base flow on the hydrograph, but below 100 ft^3/sec. A medium storm event would result in a peak flow of between 100 and 200 ft^3/sec. A large storm event would result in a peak flow that exceeded 200 ft^3/sec (Table A-7).

The representative small storm event occurred in the period December 4 to December 18, 1989. The representative medium storm event occurred in the period March 8 to March 21, 1991. The representative large storm event occurred in the period January 2 to January 18, 1993 (Table A-8).

Table A-6. Summary of Mean Time between Storm Events for Johnson Creek

Year and Parameter	Mean Time between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1989 Mean	4.78	5.64	5.21	4.41
1989 Standard Deviation	3.81	3.71	5.37	3.58
1990 Mean	4.21	4.83	4.50	4.33
1990 Standard Deviation	3.64	3.44	3.74	4.51
1991 Mean	4.30	8.44	3.39	4.81
1991 Standard Deviation	2.79	7.10	4.09	4.11
1992 Mean	5.47	8.38	4.26	4.42
1992 Standard Deviation	5.06	5.17	3.75	3.01
1993 Mean	3.56	7.09	4.83	4.32
1993 Standard Deviation	2.84	5.00	4.49	3.15
Mean for 5-Year Period	4.36	6.45	4.36	4.45
Standard Deviation for 5-Year Period	3.65	4.96	4.38	3.70

Table A-7. Number of Storm Events by Category and Year for Johnson Creek

Year	Small	Medium	Large	Total
1989	40 (60.6%)	16 (24.2%)	10 (15.2%)	66
1990	52 (74.3%)	7 (10.0%)	11 (15.7%)	70
1991	42 (61.8%)	15 (22.1%)	11 (16.1%)	68
1992	42 (68.9%)	13 (21.3%)	6 (9.8%)	61
1993	36 (54.5%)	23 (34.8%)	7 (10.7%)	66
Total 1989-1993	212 (64.0%)	74 (22.4%)	45 (13.6%)	331

Table A-8. Recession Coefficients for Storm Events in Johnson Creek

Storm Event	K_r		
	Base Flow	**Interflow**	**Runoff**
Small	0.93	0.60	N/A
Medium	0.95	0.58	N/A
Large	0.90	0.54	N/A

Cleveland, Ohio. The gauging station selected for this urban area was Station No. 04208000 on the Cuyahoga River at Independence, Ohio, a tributary to Lake Erie. This gauging station has a natural drainage basin area of 707 mi^2 and is at an elevation of 583.57 ft above mean sea level. It is located at 41 degrees 23 minutes 43 seconds North latitude and 81 degrees 37 minutes 48 seconds West longitude. This location is located 0.8 mi northeast of Independence, Ohio, and 3.0 mi downstream from Tinker Creek. The stream is a 5/6-order stream with agricultural/suburban/urban land use. The data chosen for analysis cover the years 1989 to 1993 (Table A-9).

Table A-9. Summary of Mean Time between Storm Events for Cuyahoga River

Year and Parameter	Mean Time between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1989 Mean	4.53	4.72	4.11	4.94
1989 Standard Deviation	3.20	3.71	2.88	4.09
1990 Mean	5.50	4.44	5.13	4.58
1990 Standard Deviation	5.44	3.32	3.50	4.89
1991 Mean	3.60	4.78	4.47	3.95
1991 Standard Deviation	3.12	3.38	3.65	3.31
1992 Mean	3.58	3.48	4.58	4.89
1992 Standard Deviation	2.52	2.70	3.36	3.25
1993 Mean	4.40	5.13	3.77	4.87
1993 Standard Deviation	5.10	6.22	2.50	2.45
Mean for 5-Year Period	4.21	4.46	4.37	4.62
Standard Deviation for 5-Year Period	3.96	4.00	3.21	3.75

A small storm event would result in a peak flow in the Cuyahoga River that was noticeable above the normal base flow on the hydrograph, but below 2,000 ft^3/sec. A medium storm event would result in a peak flow of between 2,000 and 4,000 ft^3/sec . A large storm event would result in a peak flow that exceeded 4,000 ft^3/sec (Table A-10).

The representative small storm event occurred in the period July 5 to July 21, 1991. The representative medium storm event occurred in the period April 18 to May 3, 1990. The representative large storm event occurred in the period April 23 to May 18, 1993 (Table A-11).

Table A-10. Number of Storm Events by Category and Year for the Cuyahoga River

Year	Small	Medium	Large	Total
1989	53 (74.6%)	12 (16.9%)	6 (8.5%)	71
1990	50 (72.5%)	12 (17.4%)	7 (10.1%)	69
1991	55 (67.1%)	17 (20.7%)	10 (12.2%)	82
1992	60 (75.0%)	18 (22.5%)	2 (2.5%)	80
1993	52 (72.2%)	9 (12.5%)	11 (15.3%)	72
Total 1989-1993	270 (72.2%)	68 (18.2%)	36 (9.6%)	374

Table A-11. Recession Coefficients for Storm Events in the Cuyahoga River

Storm Event	K_r		
	Base Flow	Interflow	Runoff
Small	0.99	0.33	N/A
Medium	0.91	0.69	0.28
Large	0.93	0.72	0.22

Williamsburg, Virginia. The gauging station selected for this urban area was Station No. 01677000, Ware Creek near Toano, VA. It is located in the York River Basin. This gauging station has a natural drainage basin area of 8.29 mi^2 and is at an elevation of 10 ft above mean sea level. The stream was a second-order stream with an urban land use. It is located at 37 degrees 26 minutes 17 seconds North latitude and 75 degrees 47 minutes 12 seconds West longitude. This station is located 0.8 mi upstream from France Swamp and 4.9 mi north of Toano, VA. The data chosen for analysis cover the years 1989 to 1993 (Table A-12).

A small storm event would result in a peak flow in Ware Creek that was noticeable above the normal base flow on the hydrograph, but below 10 ft^3/sec. A medium storm event would result in a peak flow of between 10 and 20 ft^3/sec. A large storm event would result in a peak flow that exceeded 20 ft^3/sec (Table A-13).

The representative small storm event occurred in the period June 21 to July 8, 1990. The representative medium storm event occurred in the period April 12 to April 25, 1989. The representative large storm event occurred in the period March 23 to April 11, 1992 (Table A-14).

Table A-12. Summary of Mean Time between Storm Events for Ware Creek

Year and Parameter	Mean Time Between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1989 Mean	3.59	4.05	4.94	4.78
1989 Standard Deviation	2.35	3.05	2.59	3.87
1990 Mean	3.58	4.00	5.00	4.00
1990 Standard Deviation	2.43	2.93	3.29	3.01
1991 Mean	5.07	5.44	4.83	4.25
1991 Standard Deviation	3.01	4.43	3.83	2.91
1992 Mean	6.07	4.10	5.12	5.27
1992 Standard Deviation	4.35	3.26	6.05	4.15
1993 Mean	4.20	5.00	3.91	4.82
1993 Standard Deviation	2.54	2.62	3.19	2.98
Mean for 5-Year Period	4.28	4.44	4.70	4.57
Standard Deviation for 5-Year Period	3.02	3.35	3.99	3.41

Table A-13. Number of Storm Events by Category and Year for Ware Creek

Year	Small	Medium	Large	Total
1989	43 (57.3%)	21 (28.0%)	11 (14.7%)	75
1990	53 (66.3%)	20 (25.0%)	7 (8.7%)	80
1991	56 (80.0%)	10 (14.3%)	4 (5.7%)	70
1992	53 (75.7%)	13 (18.6%)	4 (5.7%)	70
1993	42 (58.3%)	24 (33.3%)	6 (8.4%)	72
Total 1989-1993	247 (67.3%)	88 (24.0%)	32 (8.7%)	367

Table A-14. Recession Coefficients for Storm Events in Ware Creek

Storm Event	K_r		
	Base Flow	**Interflow**	**Runoff**
Small	0.97	0.43	N/A
Medium	0.94	0.32	N/A
Large	0.98	0.44	0.21

Fort Worth, Texas. The gauging station selected for this urban area was Station No. 12030102, located on the Trinity River at 32 degrees 45 minutes 06 seconds North latitude and 97 degrees 17 minutes 21 seconds West longitude on the downstream side of the bridge on Beech Street. It is also located 1,700 ft downstream of the Sycamore Creek. This gauging station has a drainage area of 2,685 mi^2 and is 478.70 ft above the National Geodetic Vertical Datum of 1929. The stream order is 5-6 with a urban/suburban land use dominating the area of the gage. The data chosen for analysis cover the years 1989 to 1993 (Table A-15).

Table A-15. Summary of Mean Time Between Storm Events for the Trinity River

Year and Parameter	Mean Time Between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1989 Mean	6.07	7.73	7.33	6.43
1989 Standard Deviation	3.15	6.21	6.22	3.98
1990 Mean	6.07	6.57	8.90	9.89
1990 Standard Deviation	3.62	6.37	4.91	7.01
1991 Mean	5.73	6.29	9.10	7.54
1991 Standard Deviation	4.01	6.17	5.54	4.75
1992 Mean	3.96	6.57	13.50	5.93
1992 Standard Deviation	2.56	4.64	8.34	2.98
1993 Mean	4.14	7.50	4.50	3.75
1993 Standard Deviation	1.91	5.48	2.58	3.11
Mean for 5-Year Period	5.07	6.88	7.56	6.08
Standard Deviation for 5-Year Period	2.95	7.34	7.45	4.35

A small storm event would result in a peak flow in the Trinity River that was noticeable above the normal base flow on the hydrograph, but below 1,500 ft^3/sec. A medium storm event would result in a peak flow of between 1,500 and 2,500 ft^3/sec. A large storm event would result in a peak flow that exceeded 2,500 ft^3/sec (Table A-16).

A representative small storm event occurred in the period September 8 to September 26, 1989. The representative medium storm event occurred in the time period January 22 to February 11, 1989. The representative large storm event occurred in the period January 28 to February 16, 1990 (Table A-17).

Table A-16. Number of Storm Events by Category and Year for the Trinity River

Year	Small	Medium	Large	Total
1989	39 (95.2%)	1 (2.4%)	1 (2.4%)	41
1990	33 (84.6%)	0 (0.0%)	6 (15.4%)	39
1991	40 (87.0%)	4 (8.7%)	2 (4.3%)	46
1992	41 (74.5%)	3 (5.5%)	11 (20.0%)	55
1993	48 (69.6%)	16 (23.2%)	5 (7.2%)	69
Total 1989-1993	201 (80.4%)	24 (9.6%)	25 (10.0%)	250

Table A-17. Recession Coefficients for Storm Events in the Trinity River

Storm Event	K_r		
	Base Flow	Interflow	Runoff
Small	0.95	0.07	0.06
Medium	0.95	0.31	0.03
Large	0.98	0.58	0.10

Phoenix, Arizona. The gauging station selected for this urban area was Station No. 09512190 on the Salt River at 24th Street in Phoenix, Arizona. It is located in the Gila River Basin. This gauging station has a natural drainage basin area of 13,391 mi^2 and is at an elevation of 1,074.80 ft above mean sea level. It is located at 33 degrees 24 minutes 56 seconds North latitude and 112 degrees 01 minutes 45 seconds West longitude. This station is located 3.6 mi southwest of the downtown post office in Phoenix, Arizona. The data chosen for analysis cover the years 1983 to 1991 (Table A-18).

A small storm event would result in a peak flow in the Salt River that was noticeable above the normal base flow on the hydrograph, but below 5,000 ft^3/sec. A medium storm event would result in a peak flow of between 5,000 and 10,000 ft^3/sec. A large storm event would result in a peak flow that exceeded 10,000 ft^3/sec (Table A-19).

Table A-18. Summary of Mean Time between Storm Events for the Salt River

Year and Parameter	Mean Time Between Storm Events (Days)			
	Spring	Summer	Fall	Winter
1983 Mean	4.64	N/A	N/A	2.92
1983 Standard Deviation	3.94	N/A	N/A	3.25
1984 Mean	None	None	5.25	2.33
1984 Standard Deviation	None	None	6.26	1.89
1990 Mean	None	None	11.00	None
1990 Standard Deviation	None	None	0.00	None
1991 Mean	9.00	None	None	None
1991 Standard Deviation	8.69	None	None	None
Mean for Period	5.80	N/A	6.40	2.80
Standard Deviation for Period	5.94	N/A	6.05	3.04

Table A-19. Number of Storm Events by Category and Year for the Salt River

Year	Small	Medium	Large	Total
1983	8 (36.4%)	7 (31.8%)	7 (31.8%)	22
1984	2 (25.0%)	4 (50.0%)	2 (25.0%)	8
1990	4 (100.0%)	0 (0.0%)	0 (0.0%)	4
1991	6 (75.7%)	0 (0.0%)	0 (0.0%)	6
Total 1983-1991	20 (67.3%)	11 (24.0%)	9 (8.7%)	40

The representative small storm event occurred in the period April 5 to April 13, 1991. The representative medium storm event occurred in the period March 1 to March 17, 1983. The representative large storm event occurred in the period October 2 to October 17, 1984 (Table A-20).

Table A-20. Recession Coefficients for Storm Events in the Salt River

Storm Event	K_r		
	Base Flow	**Interflow**	**Runoff**
Small	0.11	N/A	N/A
Medium	0.98	0.65	0.29
Large	0.99	0.75	0.44

APPENDIX B

METHOD DEVELOPMENT AND APPLICATION

Introduction

This Appendix documents the development and/or application of a range of techniques used for, or in support of, basic and advanced screening testing. The information contained here is summarized in Chapter 5.0. First, described under basic screening methodologies, is the development of a number of methodologies that can be used to classify toxicity. These methods are aimed at assessing or predicting the level of toxicity exhibited by a wet weather event or by individual samples taken during an event.

Section 4.6 highlighted the inadequacies of standard toxicity tests in addressing the range of time scales associated with wet weather events and the resulting need for modified test systems. A laboratory program to develop such modified test systems, based on a number of test endpoints, is described, together with a simple model by which an integrated measure of whole-storm toxicity can be derived from toxicity analysis of separate samples collected through a storm event. Also described are modifications of the enzyme-based Inhibitory Quotient (IQ) test for application to wet weather event toxicity assessment and the stimulatory response exhibited by the Microtox bacterial luminescence test in response to low levels of some contaminants.

Under advanced screening methodologies, the application of three methods is described that can be used to characterize toxicity following the identification of high or moderate toxicity through the initial application of basic screening procedures. The advanced screening methods described are a toxicity identification evaluation (TIE) procedure, which allows identification of specific contaminant groups giving rise to toxicity in a sample, a simple model that can be used to predict site-specific, receiving-system toxicity from hydrograph characteristics, toxicity prediction models applied to the prediction of toxicity due to heavy metals, and, finally, a simple storm sewer drainage model that can be used for estimating storm hydrographs and assist in identifying sources of contaminants.

Basic Screening Methodologies

An Introduction to Time-Scale Toxicity. As discussed in Section 1.2, existing standard methodologies for toxicity testing generally rely on test systems that operate on time scales that are not appropriate for the full range of time scales required for wet weather event analyses. A major thrust of this project has been to evaluate new methods and modify existing standard methods so that they apply to the shorter time scales relevant to wet weather intra-event assessment.

As noted previously, wet weather events are often associated with rapid changes in contaminant concentrations with peaks of high contaminant concentrations that extende for short periods of time (minutes). These concentrations can peak at levels that would be highly toxic over prolonged exposure durations (e.g., 48 hours or more). However, the relevant issue is how toxic they are over the actual exposure time in the receiving water. If concentrations are much higher than those causing toxicity on longer term exposure, another important question is that of post-exposure effects, that is toxicity caused by the short-term contaminant peak but manifested some time later, after non-polluted conditions are re-established.

This Appendix documents the laboratory program and a laboratory-based modeling effort, which were undertaken to address the above time scale and test development issues and to complement the field wet weather event assessment program.

Laboratory experiments were conducted to investigate the organismal effect of brief (or pulsed) exposures to a range of contaminant concentrations. The selected concentrations—higher than those that might be expected in wet weather discharges—provided a wide range of concentrations and would likely elicit responses in test organisms. These toxicity experiments were not intended to duplicate the full complexity of wet weather discharges, rather they were designed to assess brief exposure effects using contaminants known to occur in stormwater runoff. Toxicity testing methods were adapted to subject organisms to brief contaminant exposures (on the order of wet weather event time scales) and then remove the contaminant and monitor the post-exposure response. This research mainly investigated lethal effects but also included sublethal effects, such as reproduction, enzyme inhibition, and growth. Table B-1 shows a summary of the range of experiments performed. Concentrations were multiples of experimentally developed 24-hour LC_{50} concentrations. Organismal responses were compared between species, between contaminants, and between differing stock cultures and laboratory facilities. The research then attempted to connect the results to actual episodic pollution events, through the sampling and analysis of urban stormwater runoff events. A new test and metric for the analysis of episodic pollution events are described and demonstrated. Results are then discussed in the context of providing guidance for development of episodic pollution criteria and guidance for toxicity testing approaches to support episodic pollution monitoring and management.

Table B-1. Summary of Supplemental Time-Scale Toxicity Experiments Performed

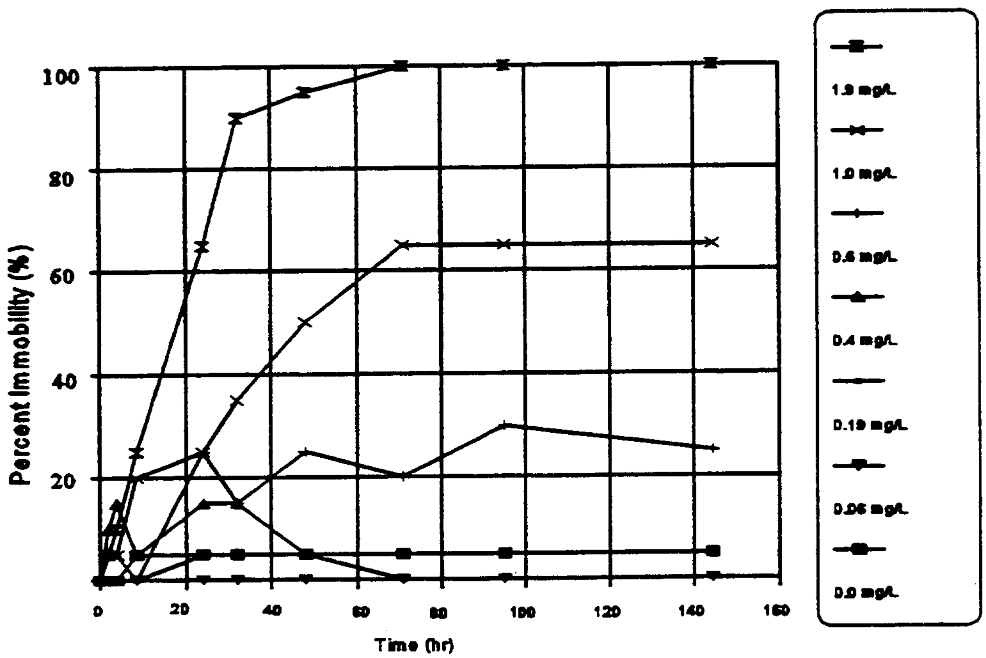
Species	Location	Substance	Concentrations (mg/L)	Exposure Durations (min)	Endpoints Measured
H. azteca	UIUC	Cd	0.06, 0.19, 0.4, 0.6, 1.0, 1.9	15, 30, 60, 120, 180, 240	lethality
		Zn	2.0, 6.4, 13.34, 20, 33.3, 64	15, 30, 60, 120, 240	lethality
	UNT	Cd	0.06, 0.19, 0.4, 0.6, 1.9	15, 60, 240	lethality
C. dubia	UIUC	Cd	0.37, 1.18, 2.5, 3.7, 6.0, 11.84	15, 30, 60, 120, 240	lethality, reproduction, enzyme inhibition
		Zn	0.15, 0.4, 1.0, 1.5, 2.5, 4.8	15, 30, 60, 120, 240	lethality
		Phenol	10, 32, 66.7, 100, 167, 320, 500	15, 30, 60, 120, 240	lethality
	UNT	Cd	0.37, 1.18, 2.5, 3.7, 6.0, 11.84	15, 30, 60, 120, 240	lethality
P. promelas	UIUC	Cd	0.4, 1.28, 2.67, 4.0, 6.67, 12.8	15, 30, 60, 120, 240	lethality, growth

UIUC = University of Illinois, Urbana-Champaign, UNT = University of North Texas.

Brief Exposure Mortality Tests: *Cadmium Exposures: Hyalella azteca, Ceriodaphnia dubia, Pimephales promelas*. The test organisms were pulse-exposed to cadmium for durations ranging from 15 to 240 min. As noted earlier, the concentrations used were designed to elicit response and are much higher than those typically seen in stormwaters. In addition, soluble metal salts were used in the tests, wheras much of the metals present in stormwaters are particulate-bound and, hence, not bioavailable.

Figure B-1 shows the immobility curve of *H. azteca* after short-term Cd exposures. This graph is representative of immobility curves for *C. dubia* and *P. promelas*, as well. Immobility is used here as the surrogate measure of mortality. Immobility approximates, but is not equivalent to, mortality, since some organisms regain mobility. In most cases, organisms that were observed as immobile remained immobile and were obviously dead as indicated by signs of decomposition (loss of pigment, morphological alterations, and growth of decaying fungus).

Figure B-1. Percent Immobility of UIUC *H. azteca* after 60-min Cd Exposure



Note that in Figure B-1 time on the x-axis is in hours beginning at the initial time of exposure. Mortality did not generally occur during the exposure period; rather mortality was delayed and occurred after organisms were placed in clean water. Although exposure times lasted for only 15 to 240 min, mortality continued up to 70 to120 hr after the initial exposure period (longer for *P. promelas*). The maximum percent mortality increased with increasing Cd concentration and increasing time of exposure. The time at which the maximum mortality occurred with increasing Cd concentration and duration of exposure.

Information in mortality curves was summarized by calculating 12-, 24-, 48-, 72-, 96-, 120-, and 144-hour post-exposure median lethal exposure times (PE-LET_{50}) for each concentration. The x-hr PE-LET_{50} is the exposure time necessary to cause 50% mortality of the test population within x hours following the exposure. This x-hr PE-LET_{50} differs from normal LT_{50} values, which are based on time until death. This term instead refers to the time of exposure that causes eventual death even after the contaminant is removed. PE-LET_{50} values were calculated from linear regression lines from plots of percent mortality at x-hours versus the logarithm of the exposure duration (Figure B-2). This method is a modified version of the Litchfield and Wilcoxon (1949) method for determination of LC_{50} and LT_{50} values. Confidence limits were also calculated by the Litchfield and Wilcoxon method. As an example of this method, Table B-2 shows the results of a 1.0-mg/L Cd exposure on *H. azteca* at 48 hours post-exposure. Similarly calculated PE-LET_{50} values are plotted in Figures B-3 to B-5 for *H. azteca*, *C. dubia* and P. promelas.

Table B–2. Percent Mortality of *H. azteca* at 48 hr after a 1.0–mg/L Cd Exposure

Exposure Duration (min)	Percent Effect
15	0
30	25
60	50
120	85
180	100
240	100

Figure B-2. PE-LET$_{50}$ Determination for *H. azteca* Exposed to 1.0-mg/L Cd

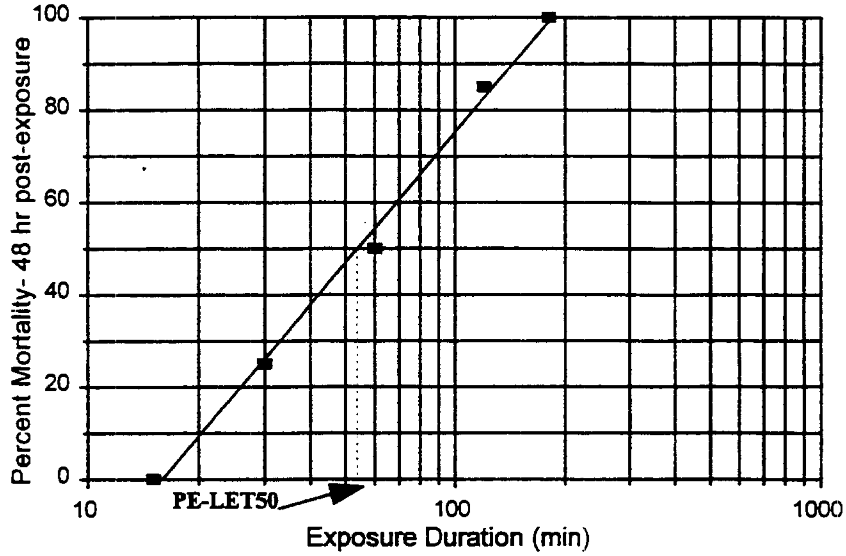


Figure B-3. Change in PE-LET$_{50}$ over Time for UIUC *H. azteca* Cd Exposure

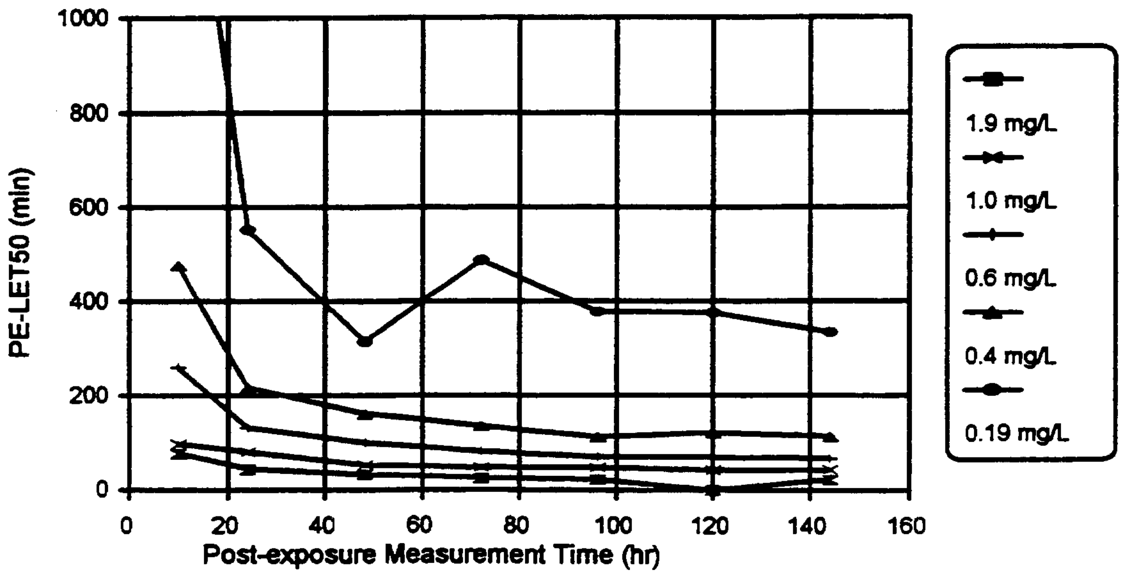


Figure B-4. Change in PE-LET50 over Time for UIUC *C. dubia* Cd Exposure

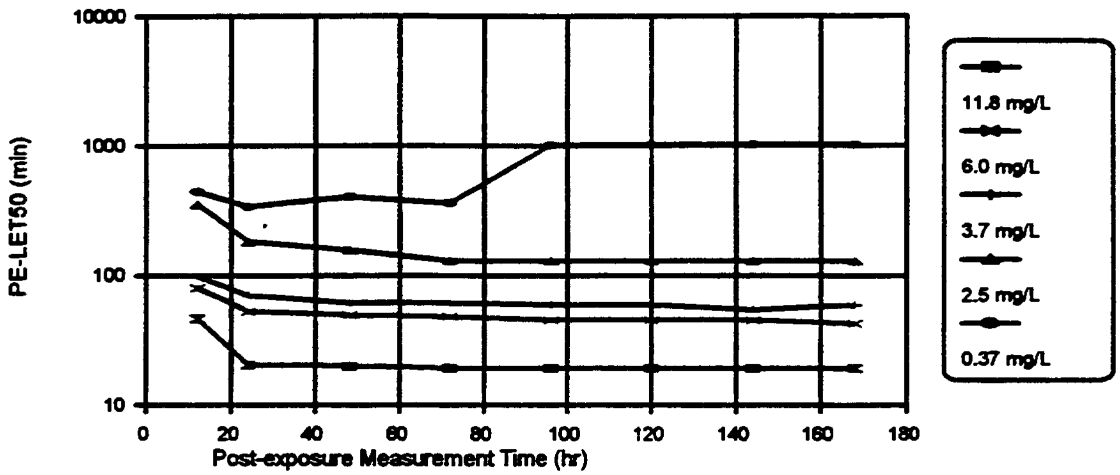
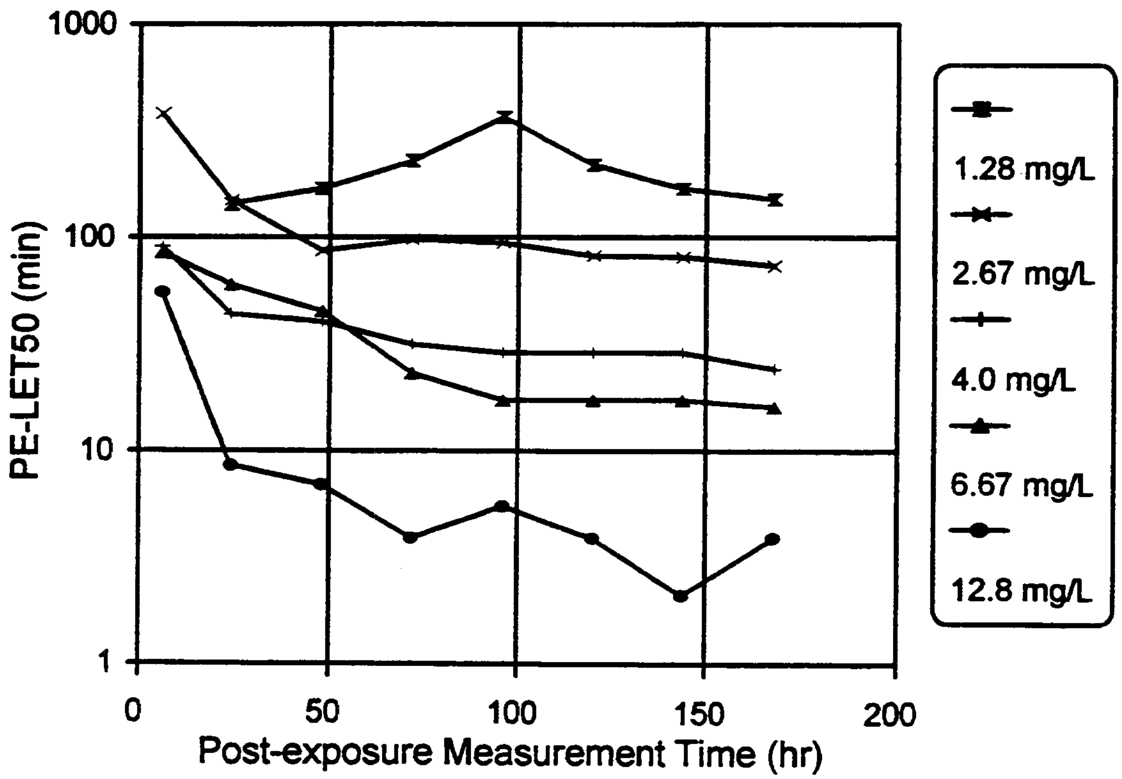
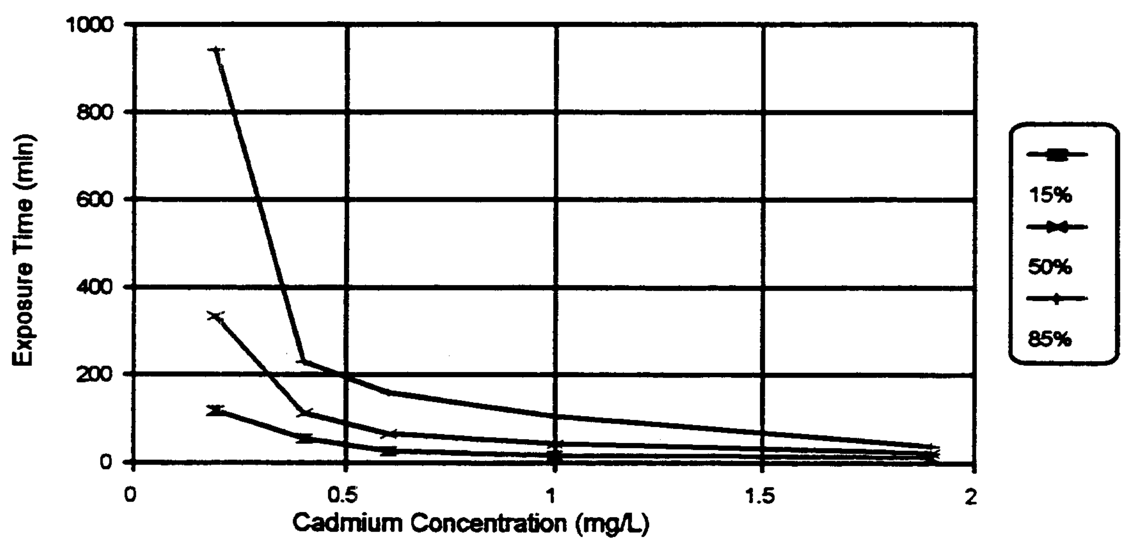


Figure B-5. Change in PE-LET$_{50}$ over Time for UIUC *P. promelas* Cd Exposure



The observed delayed mortality caused PE-LET$_{50}$ values (an inverse measure of effect) to rapidly decrease soon after the exposure (Figure B-3). The curves then stabilized and approached a slope of zero, indicating that the maximum effect of the exposure was reached. The PE-LET$_{50}$ value at this point can be termed the ultimate PE-LET$_{50}$, which is the exposure time that ultimately will cause 50% mortality in the test population. The ultimate PE-LET$_{50}$ was generally reached by 120 hours after the exposure for *H. azteca* (Figure B-3), by 96 hours for *C. dubia* (Figure B-4), and not by 168 hours for *P. promelas* (Figure B-5). At higher exposure concentrations, this ultimate PE-LET$_{50}$ was reached more quickly than at low concentrations, indicating that the effects of high level stress are displayed quickly while low level stress might require some time for the effect to be developed (delayed effect). Figure B-6 illustrates the acute effect of Cd exposure as a function of exposure time and concentration. As the concentration of exposure increases, the duration of exposure necessary to elicit a particular percent effect decreases and vice versa. It is difficult to tell from these data if the curves asymptotically approach zero from both directions or if some other threshold exists.

Figure B-6. Percent Immobility of UIUC *H. azteca* as a Function of Exposure Time and Cd Concentration



Brief Exposure Mortality Tests: Zinc Exposures: H. azteca, C. dubia. Results of short-term *H. azteca* and *C. dubia* exposures to Zn were similar to those for Cd exposure (Figures B-7 and B-8). Organism mortality was delayed after the exposure period. The concentrations of Zn used in *H. azteca* exposures were much larger than for Cd exposures due to greater *H. azteca* tolerance to Zn. However, Zn concentrations used in *C. dubia* exposures were lower, which reflects the differences in species sensitivities to different contaminants. The ultimate PE-LET_{50} was generally reached by 120 hours after the exposure for *H. azteca* (Figure B-7) and by 96 hours for *C. dubia* (Figure B-8).

Brief Exposure Mortality Tests: Phenol Exposures: C. dubia. Representative results of brief phenol exposures are seen in Figure B-9. No significant delayed effects were observed for any of the phenol exposure regimes, which ranged as high as 240-min exposure to 500-mg/L phenol (50 times the 24-hr LC_{50} value). All exposure regimes caused less than 20% immobility; control immobility ranged from 0% to 25%. Exposure durations of 6 to 48 hours were required to produce any lasting effect on *C. dubia*. Interestingly, organisms in the 100-, 166.7-, 320-, and 500-mg/L concentrations were immobile at the end of each exposure period (15 to 240 min), yet quickly recovered when placed in the dilution water. This represents a tremendous potential for recovery from brief phenol exposures. It also indicates that short-term phenol toxicity has reversible effects, unlike the irreversible effects of cadmium and zinc.

Figure B-7. Change in PE-LET_{50} over Time for UIUC *H. azteca* Zn Exposure

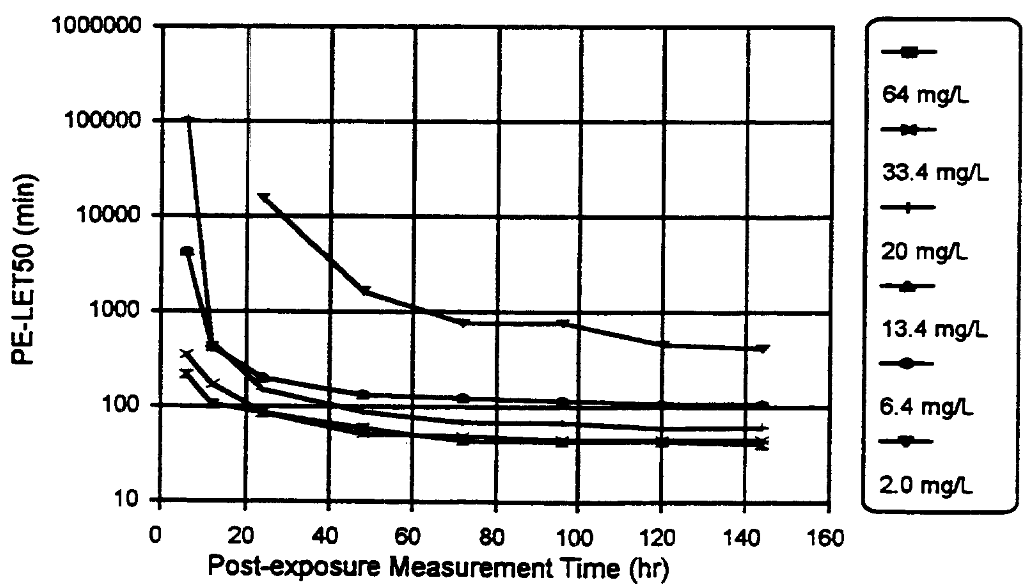


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Figure B-8. Change in PE-LET$_{50}$ over Time for UIUC *C. dubia* Zn Exposure

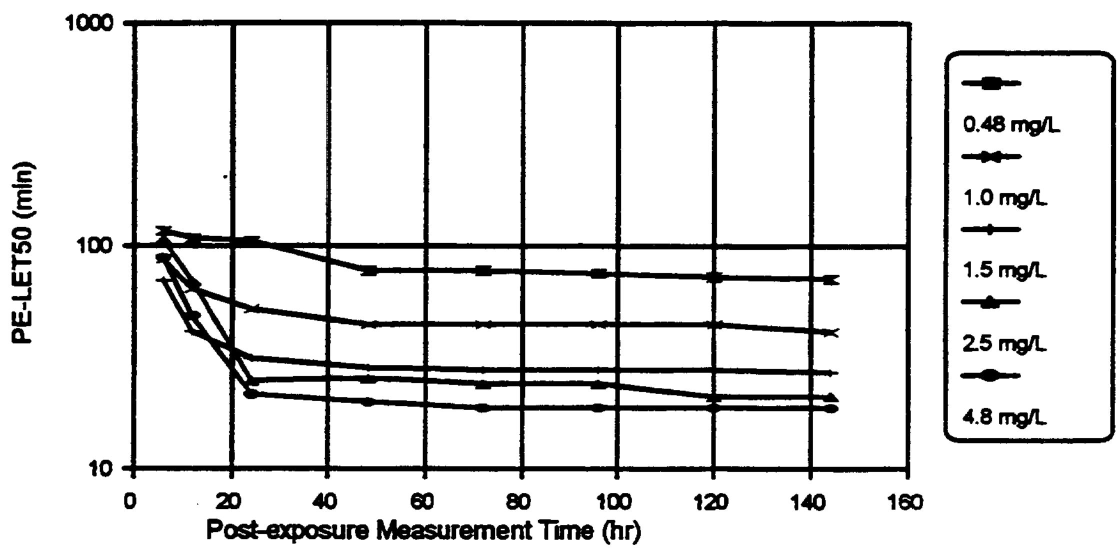
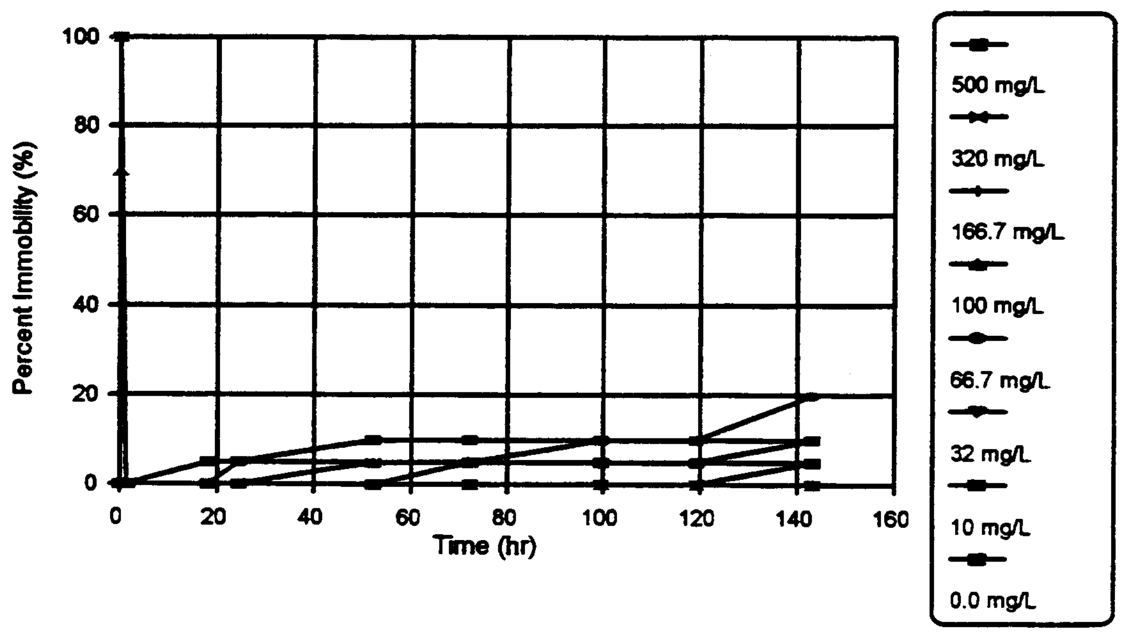


Figure B-9. Percent Immobility of UIUC *C. dubia* after 30 min Phenol Exposure



Summary. Delayed lethal effects were observed for *H. azteca*, *C. dubia*, and *P. promelas* after brief cadmium exposure and for *H. azteca* and *C. dubia* after brief zinc exposure. Other authors have also documented the presence of delayed lethal effects in the amphipod *Gammarus pulex* after brief exposure to Lindane, permethrin, cadmium, and cyanide (Abel, 1980a; Abel, 1980b; Abel and Gardner, 1986) and in *P. promelas* after brief exposure to chlorpyrifos, endrin, and fenvalerate (Jarvinen et al., 1988). While delayed mortality was observed for cadmium and zinc exposures, recovery of *C. dubia* was observed after brief phenol exposure. Green et al. (1988) also reported the recovery of *Asellus aquaticus* after brief phenol exposure. These results suggest that care must be exercised when assessing wet weather discharge toxicity. Not only is there the possibility of delayed effects from brief exposure, there is a potential for recovery. Clearly, a modification of toxicity assessment procedures is needed that addresses both brief exposure issues and post-exposure effect analysis.

The PE-LET_{50} metric was effectively used to measure ultimate toxic effects with the consideration of delayed effects and recovery. Other metrics that incorporate delayed effects have been previously proposed. Although the calculation method is similar, the PE-LET_{50} differs from other commonly used or proposed toxicity metrics (Table B-3). The PE-LET_{50} differs from the LC_{50} and LT_{50} primarily in that it incorporates post-exposure observation. The PE-LET_{50} also differs from other metrics that do include post-exposure observation.

Pascoe and Shazili (1986) proposed a pe-LT_{50} (post exposure median lethal time), which is the time until 50 percent mortality, measured beginning after the exposure period. This metric sounds similar to the PE-LET_{50}, but is fundamentally different. The time that is actually measured in the pe-LT_{50} is the time to death, not the time of exposure which causes eventual death. While this metric incorporates post-exposure observation, it does not give information on exposure durations which cause ultimate effects;it simply provides information on the speed at which the toxicant produces an effect. Abel (1980b) proposed the use of a 20-day median lethal exposure time. This metric is very similar to the PE-LET_{50} and could actually be described as a 20-day PE-LET_{50}. There is more utility, however, in an ultimate PE-LET_{50} which will change in measurement time with a change in species used. For instance, as seen in this study, a 120-hour PE-LET_{50} is sufficient for estimating the ultimate effect (or ultimate PE-LET_{50}) for *H. azteca*, while *C. dubia* requires only a 96-hr PE-LET_{50}, and *P. promelas* requires greater than a 168-hr PE-LET_{50}. It was also seen that the time required for ultimate PE-LET_{50} determination decreased with increasing magnitude of exposure. Table B-4 summarizes the ultimate PE-LET_{50} values from tests performed at UIUC.

The plots of exposure time versus toxicant concentration showed curves of typical form. They agree with the form of the simple C x T model and the Mancini model (discussed elsewhere in this Appendix). Fitting the data to the C x T model yields the constant K1 for each of the species and contaminants; however, this constant has no physical significance. Data can also be fitted to the Mancini model, yielding the constants k_u/CD and k_r. The k_r constant (depuration rate) was generally very small (approaching zero) due to delayed effects. The delayed effects, however, do suggest that models such as the Mancini model used to estimate the effect of time varying exposures should use pulse exposure tests to fit data rather than continuous exposure tests (Hickie et al., 1995).

Table B-3. Comparison of PE-LET$_{50}$ Metric with Other Used and Proposed Metrics

Metric	Test conditions	Test characteristic measured	Information provided
LC50	Continuous exposure to range of concentrations	Lethality at end of set duration exposure	The **concentration** necessary to produce a lethal response within a set duration
LT50	Continuous exposure to single concentration	Lethality at set times during exposure	The **speed** of a toxic response
pe-LT50	Single concentration exposure, with subsequent post-exposure observation	Lethality at set times during post-exposure observation	The **post-exposure time** necessary to observe lethality
20 day LT50	Single concentration exposure for a range of exposure durations, with subsequent post-exposure observation	Lethality at 20 days post-exposure	The **exposure time** required to produce lethality within 20 days
PE-LET50	Single concentration exposure for a range of exposure durations, with subsequent post-exposure observation	Lethality at set times during post-exposure observation	The **exposure time** necessary to ultimately produce lethality

Brief Exposure Reproduction Tests. Tests were performed in which <24-hour old *C. dubia* were subjected to short-term Cd exposures followed by measurement of reproduction rates. Test results are summarized in Table B-5, and a representative plot is shown in Figure B-10. Each group of experiments (grouped by exposure time) was performed on a different day or at a different time, and control group data are provided in Table B-5. Neonate production was typically reduced at exposure concentrations just below lethal levels of 6 to 11.8 mg/L. However, these reductions were only statistically significant (one-sided Dunnett's t-test at α=0.05) for three exposure regimens. Other exposure regimens that reduced neonate production could not be statistically validated due to the low number of surviving individuals. This sublethal effect apparently occurred within a narrow range between indistinguishable effects and lethal effects. Delayed reproductive onset decreased neonate production for two concentrations after 240-min exposure. No neonates were produced until 6 or 7 days after 2.5-mg/L and 3.7-mg/L exposures, respectively.

Table B-4. Summary of Ultimate PE-LET$_{50}$ Values and Time after Exposure When Ultimate PE-LET$_{50}$ Values Were Reached for UIUC Organisms

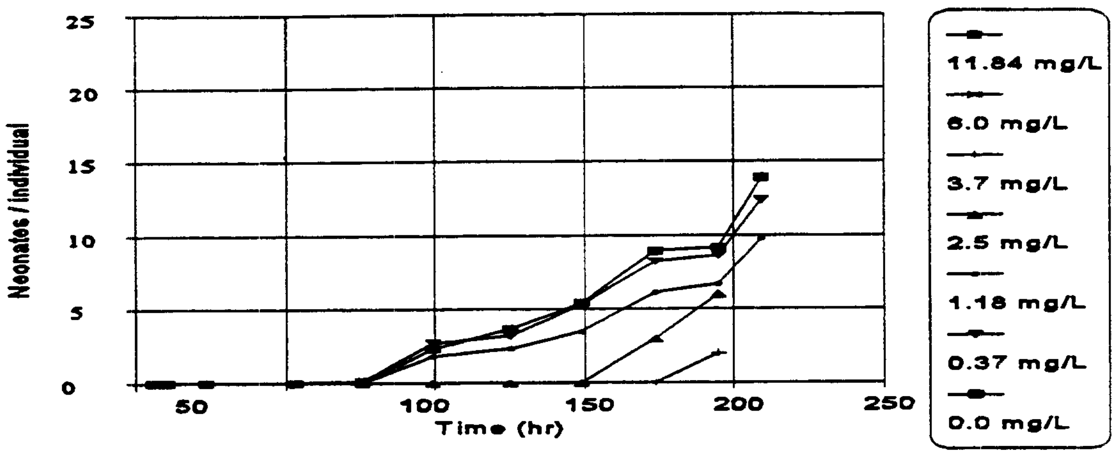
Species	Substance	Concentration (mg/L)	Ultimate PE-LET$_{50}$ (min)	Time Reached (hr)
H. azteca	Cd	0.19	335	144
		0.4	113	96
		0.6	67	144
		1.0	42	120
		1.9	23	96
	Zn	2.0	415	144
		6.4	107	120
		13.4	61	120
		20	60	120
		33.4	45	96
		64	43	96
C. dubia	Cd	0.37	1013	96
		2.5	130	72
		3.7	62	48
		6.0	46	96
		11.8	20	48
	Zn	0.15	705	144
		0.48	71	144
		1.0	41	144
		1.5	27	144
		2.5	21	120
		4.8	19	72
P. promelas	Cd	1.28	151	168
		2.67	73	168
		4.0	24	168
		6.67	16	168
		12.8	2	144

Table B-5. UIUC *C. dubia* 8-day Cumulative Mean Neonate Production

Exposure Time (min)	Cd Concentration (mg/L)	N	Mean (# neonates)	Range (# neonates)
15	0.0	17	9.59	(4-19)
	0.37	18	8.78	(1-16)
	1.18	19	6.64a	(3-11)
	2.5	19	9.36	(4-13)
	3.7	15	11.20	(5-17)
	6.0	18	11.22	(3-18)
	11.84	16	9.19	(6-13)
30	0.0	19	9.68	(3-15)
	0.37	19	9.79	(4-12)
	1.18	19	9.68	(6-15)
	2.5	16	10.06	(5-15)
	3.7	15	8.07	(5-10)
	6.0	17	8.29	(1-13)
	11.84	2	11.5	(10-13)
60	0.0	17	6.06	(2-10)
	0.37	19	6.84	(3-10)
	1.18	16	7.00	(3-12)
	2.5	17	5.53	(2-9)
	3.7	16	5.56	(2-8)
	6.0	1	6.00	
	11.84	0	0[b]	
120	0.0	17	12.94	(8-17)
	0.37	17	12.94	(5-17)
	1.18	18	13.22	(7-17)
	2.5	5	11.40	(7-16)
	3.7	2	7.00[a]	(1-13)
	6.0	0	0[b]	
	11.84	0	0[b]	
240	0.0	5	9.60	(6-14)
	0.37	13	8.31	(5-13)
	1.18	16	6.50[a]	(1-12)
	2.5	1	6.00	
	3.7	1	2.00	
	6.0	0	0[b]	
	11.84	0	0[b]	

[a] Dunnett's t-test indicates value significantly less than control (α=0.05)
[b] Exposure caused 100% mortality

Figure B-10. Cumulative Neonate Production of UIUC *C. dubia* after 240-min Cd Exposure



Brief Exposure Enzyme Inhibition (IQ) Tests. Results of the enzyme inhibition test also indicated potential for recovery from sublethal effects after the exposure period. Figures B-11 and B-12 show representative results of enzyme inhibition tests. Galactosidase enzyme activity was generally inhibited directly following the exposure period, yet recovery of enzyme activity was observed during the following 48 hours. Figure B-13 shows the maximum percent enzyme inhibition for each exposure regimes. The maximum percent effect generally increased with increasing exposure times and with increasing Cd concentrations. The mean time of maximum enzyme inhibition was 3.30 hours (with a 95% confidence interval of 2.65 to 3.96) after the onset of exposure. Since several of the exposure times were less than 3 hours, often the maximum percent effect was not reached until after the exposure period had ended. For these very brief exposure periods (Figure B-12), enzyme inhibition was actually lower directly after the exposure period, reached a maximum approximately 2-4 hours later, and then decreased as the organisms recovered. This time gives some indication of the total time for the transfer of toxicants to the site of action and response manifestation.

Figure B-14 shows organism recovery time—the time at which the percent enzyme inhibition of the population dropped below 20%—after brief cadmium exposure. Twenty percent was chosen since the control population response often fluctuated below 20% inhibition. Recovery time also was a function of exposure concentration and exposure time. The time necessary for recovery increased with increasing exposure time and with increasing cadmium concentration.

Figure B-11. Percent Inhibition of UIUC *C. dubia* Galactosidase Enzyme after 120-min Cd Exposure

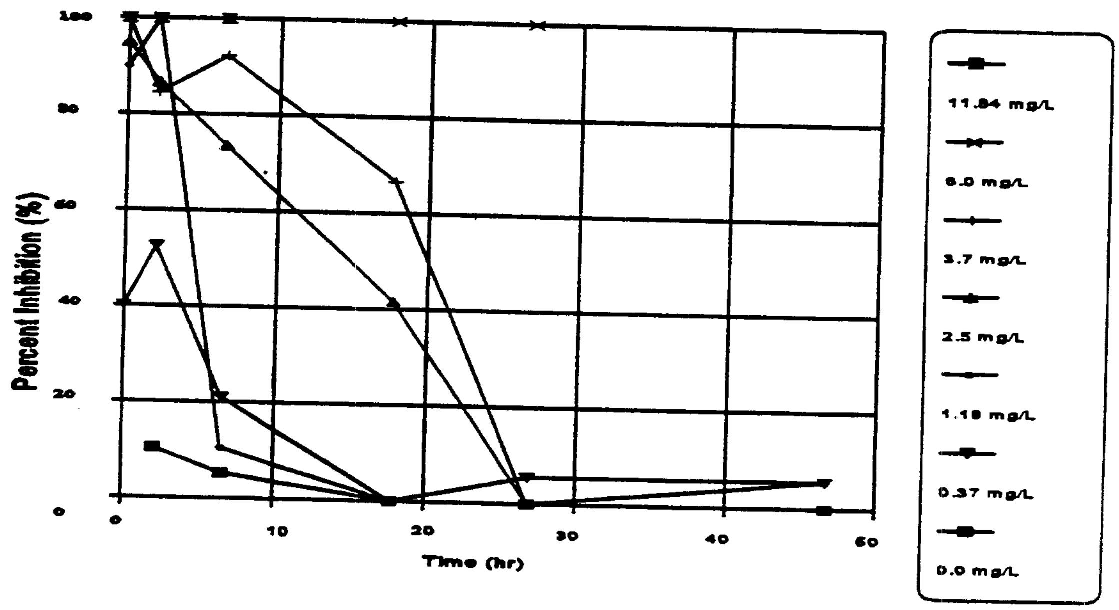


Figure B-12. Percent Inhibition of UIUC *C. dubia* Galactosidase Enzyme after 15-min Cd Exposure

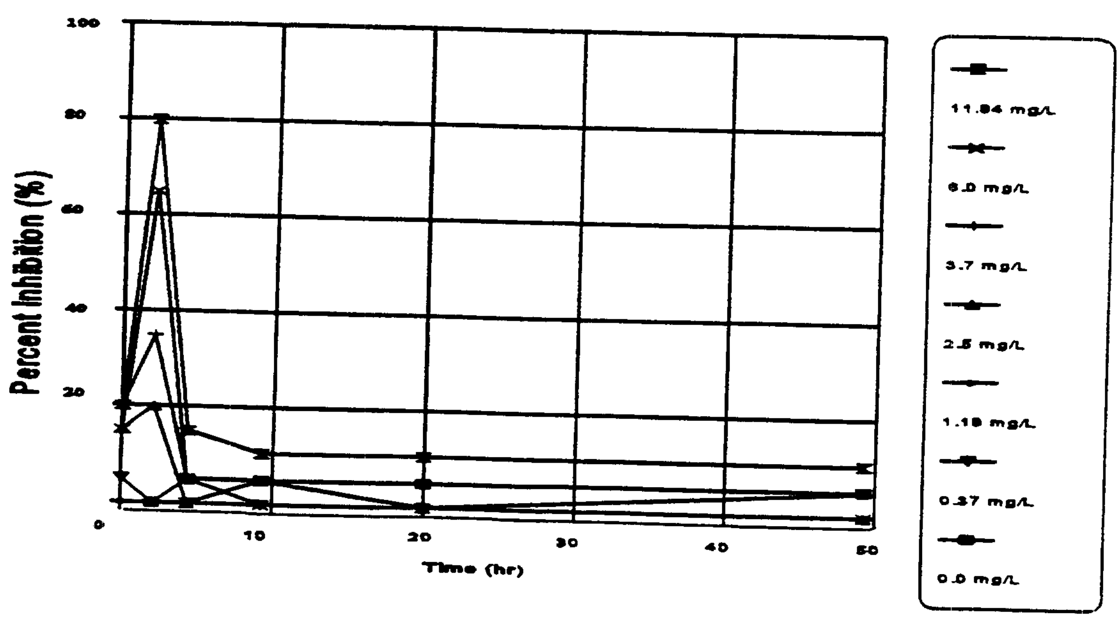


Figure B-13. Maximum Percent Times and Exposure Concentrations of Cadmium

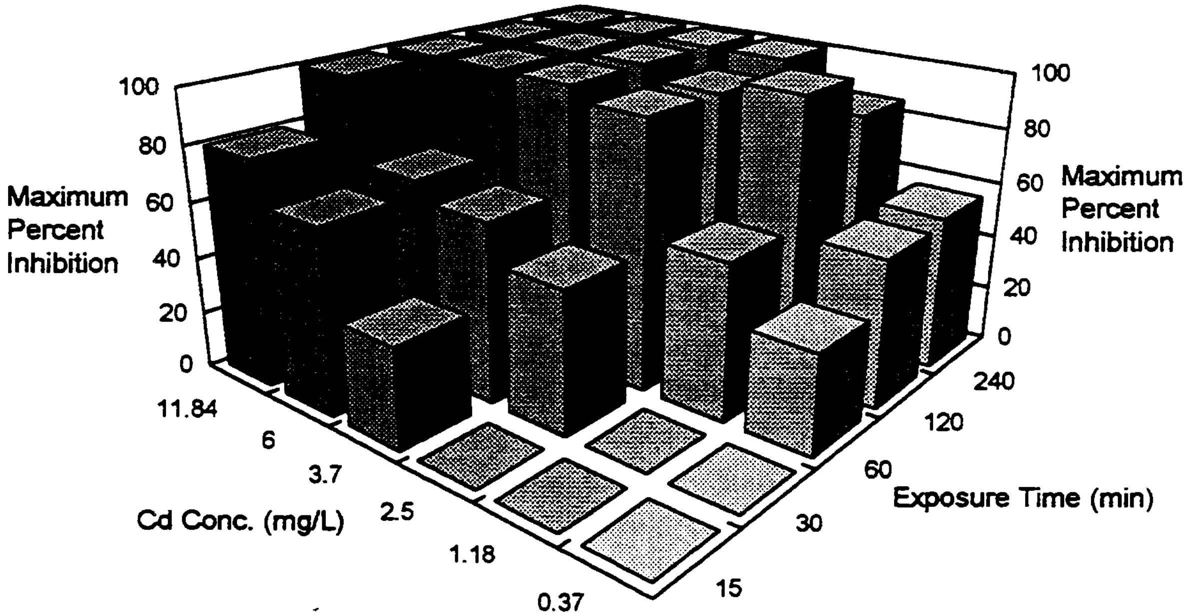
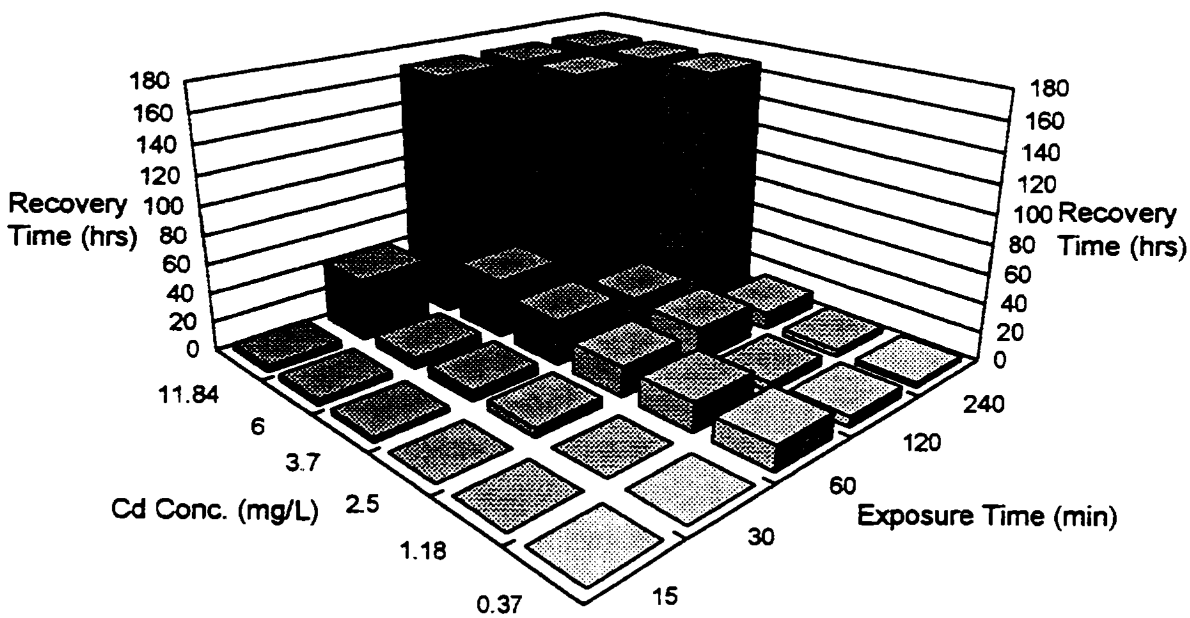


Figure B-14. Recovery Time for Enzyme Activity of UIUC C. *dubia* after Brief Cd Exposures



Brief Exposure Growth Test. *P. promelas* tests were initially designed only for PE-LET_{50} determination (lethality measurement). During the test, however, it was noticed that organisms surviving brief exposures were somewhat smaller than control populations, so growth of *P. promelas* was measured at the termination of the test. Since the experiment was originally designed only for PE-LET_{50} determination, organisms in each treatment were pooled for post-exposure observation and a pooled weight for each treatment was measured. The pooled weight was then divided by the number of survivors in each treatment to obtain a mean dry weight/surviving individual. This method meant that variances of mean dry weights could not be calculated except for control populations (since controls were conducted with each group of exposure duration treatments). Table B-6 shows the mean dry weights of *P. promelas* exposed to cadmium pulses. The mean dry weight for all control organisms was 0.159 mg with a 95% confidence interval of 0.078 to 0.241 mg. Statistical analyses could not be performed among treatments because of the lack of replication. However, in six treatments the mean dry weights were below the lower limit of the 95% confidence interval for control organisms. This decrease in mean dry weight occurred in treatments with exposure regimes just below lethal levels (generally high exposure concentrations and long exposure durations). Jarvinen et al. (1988) also showed that *P. promelas* exposed to pulses of chlorpyrifos experienced growth suppression. As with the effect of decreased reproduction in *C. dubia*, the effect of decreased growth in *P. promelas* appears to occur in a narrow range between indistinguishable effects and lethal effects.

Comparison of Brief Exposure and Continuous Exposure. For *C. dubia*, the results of brief exposure tests with post-exposure observation were compared to results of continuous exposure tests. PE-LET_{50} values were calculated for brief exposure tests, and LT_{50} values were calculated for continuous exposure tests. LT_{50} values represent time of continuous exposure at which 50% mortality occurs. Figure B-15 compares the PE-LET_{50} and LT_{50} values for cadmium exposures. At approximately 1,000 minutes of exposure, continuous exposure and brief exposure with post-exposure observation produce the same response. At times of exposure less than approximately 1,000 minutes, the two curves diverge. Brief exposure with post-exposure observation tests produced a more severe response than continuous exposure tests. Continuous exposure tests, since they ignore delayed effects, can underestimate the effect of brief toxic exposures, particularly for fast acting toxicants. At longer exposures times, the two methods approximate each other, since delayed effects are less important when exposure times are long. Abel and Gardner (1986) showed the same effect with *Gammarus pulex* exposed to pulses of cadmium. Median lethal exposure times (measured similarly to PE-LET_{50}s) were consistently less than median survival times (LT_{50}s), demonstrating an underestimation of effect by the continuous exposure regime. In assessing toxicity from brief exposures it is important to consider both mechanisms of toxic action, and the time required for response induction i.e., to understand the nature of the toxicants in relation to the time to induce response (Section 4.3).

Figure B-15. Comparison of PE-LET$_{50}$ and LT$_{50}$ Values for UIUC *C. dubia* Cd Exposure

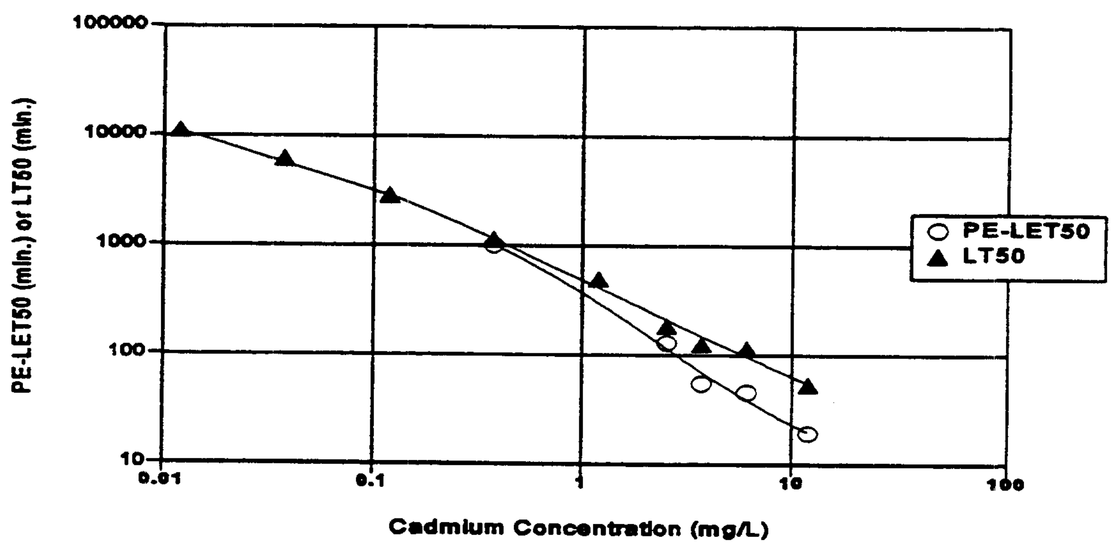


Figure B-16 compares the continuous exposure and brief exposure with post-exposure observation for zinc exposure. Brief exposure with post-exposure observation tests again show a more severe response than continuous exposure tests. For the case of zinc exposure, the difference between the PE-LET$_{50}$ and LT$_{50}$ values is much greater than for cadmium exposure. Again the continuous exposure method would underestimate the effect of brief toxic exposures. The two curves for zinc exposure also converge when the exposure time reaches approximately 1,000 minutes. At longer exposure times the results from each method are approximately the same.

Table B-6. Mean Dry Weight of UIUC *P. promelas* 7 Days after Brief Cd Exposure

Concentration (mg/L)	Exposure Time (min.)	N	Mean Weight/fish (mg)
0.4	Control	9	0.167
	15	9	0.233
	30	10	0.200
	60	9	0.144
	120	10	0.110
	240	7	0.171
1.28	Control	15	0.267
	15	13	0.231
	30	15	0.200
	60	14	0.214
	120	10	0.100
	240	8	0.125
2.67	Control	20	0.150
	15	20	0.150
	30	18	<0.056[a]
	60	11	<0.091[a]
	120	6	<0.167[a]
	240	2	<0.500[a]
4.0	Control	14	0.107
	15	16	0.063[b]
	30	5	0.040[b]
	60	3	0.067[b]
	120	0	0
	240	0	0
6.67	Control	18	0.106
	15	10	0.140
	30	8	0.113
	60	2	0.05[b]
	120	0	0
	240	0	0
12.8	Control	18	0.106
	15	5	0.040[b]
	30	2	0.050[b]
	60	0	0
	120	0	0
	240	0	0

[a] weight of fish was not detectable, so calculation was based on detection limit values.

[b] mean dry weight was below lower 95% confidence limit for control organisms.

Figure B-16. Comparison of PE-LET$_{50}$ and LT$_{50}$ Values for UIUC *C. dubia* Zn Exposure

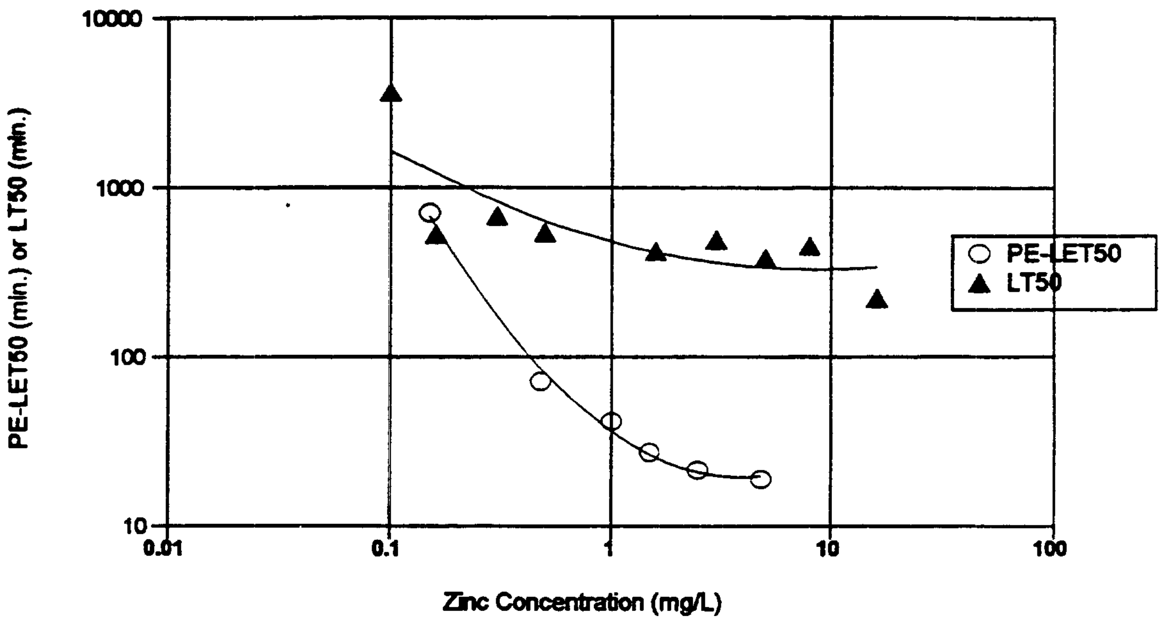


Figure B-17 compares the PE-LET$_{50}$ values and LT$_{50}$ values for phenol exposure. In this case, the brief exposure with post-exposure observation test produced a less severe response than the continuous exposure test. This is due to the fact of organism recovery after the phenol exposure. In this case, the continuous exposure (LT$_{50}$ method) would overestimate the actual effect of pulse exposure. The two curves again begin to converge as phenol concentrations drop below 10 mg/L and exposure times approach 1,000 minutes. Another interesting fact is that the PE-LET$_{50}$ curve is fairly flat. This indicates a possible minimum threshold for exposure time but this data does not support threshold determination. Even as phenol concentrations increase from 10 mg/L to 500 mg/L PE-LET$_{50}$ values do not decrease. A minimum threshold for 50% effect, in this data, occurs at approximately 200 minutes of exposure.

Between Species Comparison of Brief Exposure Tests: Cadmium Exposures. Brief exposure Cd tests were performed on *H. azteca*, *C. dubia*, and *P. promelas*. The results were compared to investigate differences in brief exposure response among species. Figure B-18 compares the brief exposure toxic response (in terms of PE-LET$_{50}$ values over the range of Cd concentrations used) among species. An analysis of covariance procedure was used to compare trends among species and contaminants (SPSS software). Tukey's honestly significant difference test was used to perform multiple comparisons among species. The alpha value for all tests was 0.05. Those curves which lie closest to the origin represent more sensitive populations, since a shorter time of exposure is required to produce a 50% response given a fixed cadmium concentration. *H. azteca* is the most sensitive of the three species to short-term cadmium exposures, with *C. dubia* being the least sensitive, and *P. promelas* falling in between. Each of the curves appears to be linear on a log/log scale within the range of observation. This indicates that if thresholds for cadmium exposure exist, they are very low and outside the range of concentration and exposure times examined (<0.06 mg/L and <3.93 min respectively). Notice also that the slope of the curves for *H. azteca* and *C. dubia* are approximately equivalent, but the slope of the *P. promelas* curve is considerably steeper. In fact, if the curve for *P. promelas* were extended, it would cross both other lines and would be the most sensitive species at short exposure times and the least sensitive at longer exposure times. This difference in slope is probably due to a difference in mechanisms of cadmium toxicity between the fish and the invertebrates.

Figure B-17. Comparison of PE-LET$_{50}$ and LT$_{50}$ Values for UIUC C. *dubia* Phenol Exposure

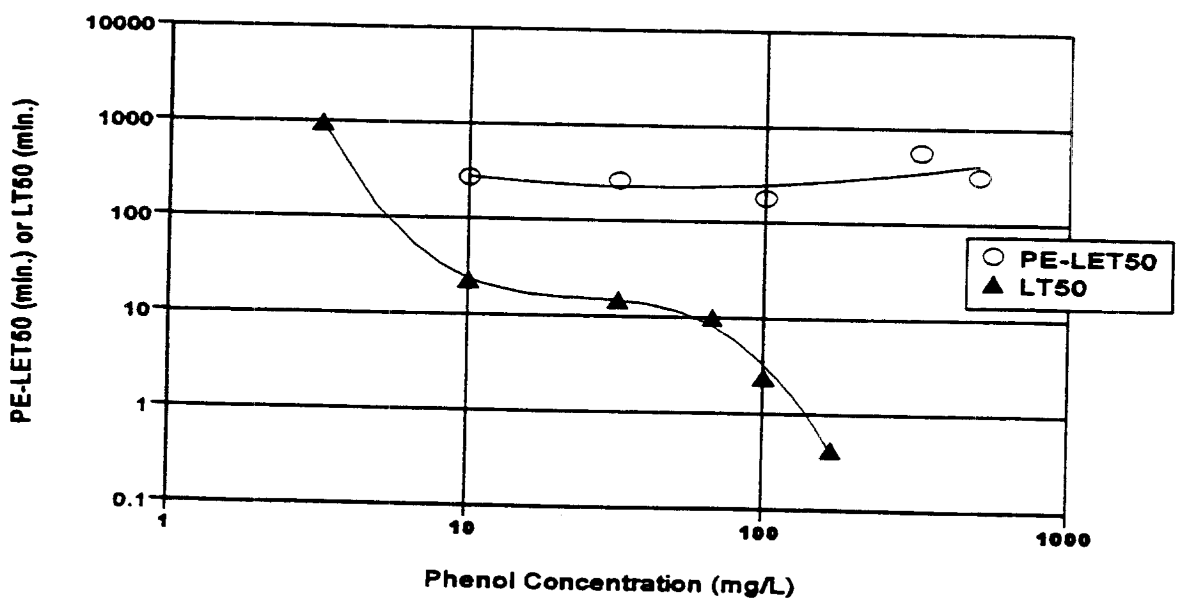
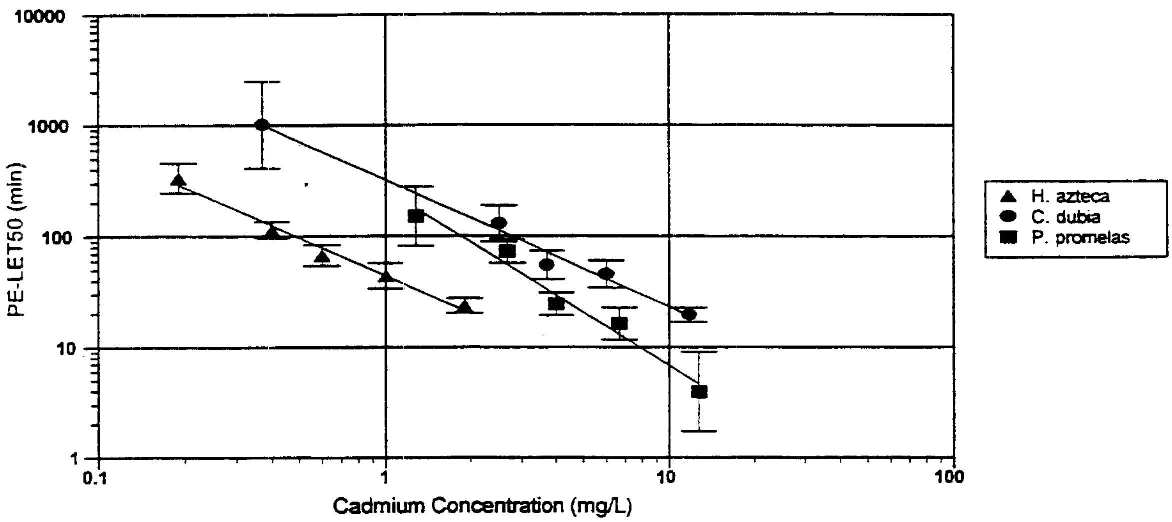
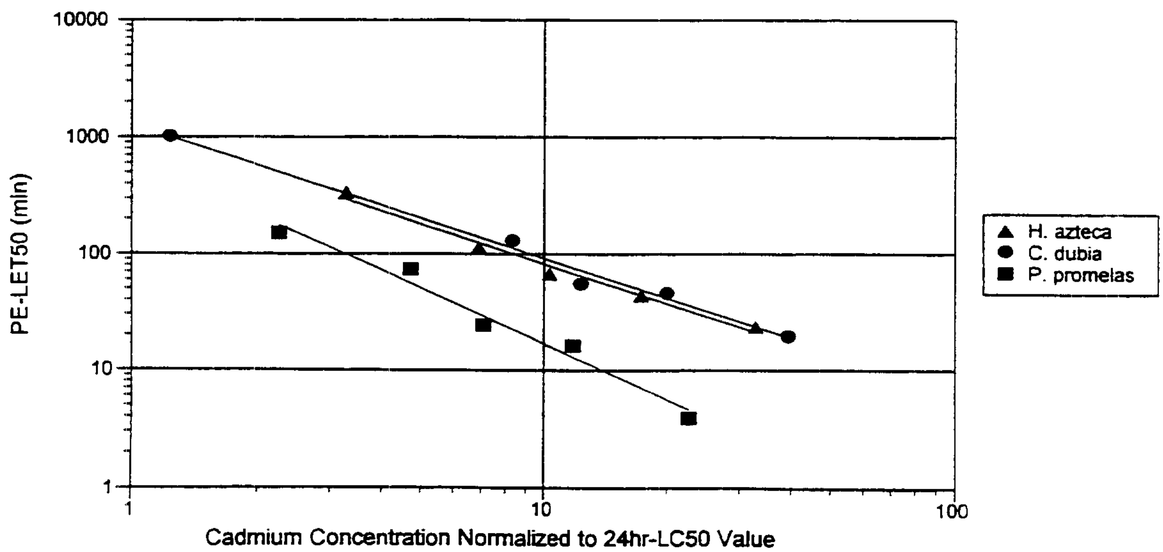


Figure B-18. Comparison of PE-LET$_{50}$ Values for Different Species over a Range of Cd Concentrations



To determine whether differences in sensitivities observed among species were due to differences in their sensitivity to Cd or to differences in sensitivity to short-term exposures, the PE-LET$_{50}$ values were plotted against Cd concentrations which had been normalized to the 24-hr LC$_{50}$ values for that organism. Figure B-19 compares the species sensitivity on a normalized basis. Curves for *H. azteca*

Figure B-19. Comparison of PE-LET$_{50}$ Values for Different Species over a Range of Cd Concentrations Normalized to 24-hr LC$_{50}$ Values



and *C. dubia* lie directly on top of each other showing that the differences observed in short-term Cd exposure tests are entirely attributable to inherent differences in species sensitivity to Cd, and these differences are merely a reflection of differences observed at longer term exposures (24-hr LC_{50}). The response of *P. promelas*, however, was still different than for the two invertebrate species. *P. promelas* was considerably more sensitive to short-term Cd exposures than *H. azteca* or *C. dubia* on a normalized Cd concentration basis. This indicates that the 24-hr LC_{50} was not a good indicator of the short-term exposure response of *P. promelas* relative to other species. Even though *C. dubia* is more sensitive than *P. promelas* when 24-hr LC_{50}s are considered, *P. promelas* is more sensitive than *C. dubia* to short-term exposures (Figure B-19). This fact is related to the slope of the curves in Figure B-18. Because the *P. promelas* curve differs in slope from the other species, it is less sensitive (farther from the origin) at longer exposure times yet more sensitive (closer to the origin) at shorter exposure times. This is again probably due to a difference in the mechanism or multiple mechanisms of Cd toxicity between the *P. promelas* and the two invertebrate species.

Zinc Exposures. Figure B-20 compares the relative sensitivities of *H. azteca* and *C. dubia* to short-term zinc exposures. *C. dubia* is the most sensitive to Zn exposure, whereas *H. azteca* was more sensitive to Cd exposure. Notice that the curves are not straight lines as was the case with Cd exposures. The curves appear to reach asymptotes in both the x and y direction indicating that there is a threshold zinc concentration and a threshold duration of exposure below which no toxicity occurs. The thresholds for *C. dubia* appear to be much lower than those for *H. azteca*.

Figure B-20. Comparison of PE-LET_{50} Values for Different Species over a Range of Zn Concentrations

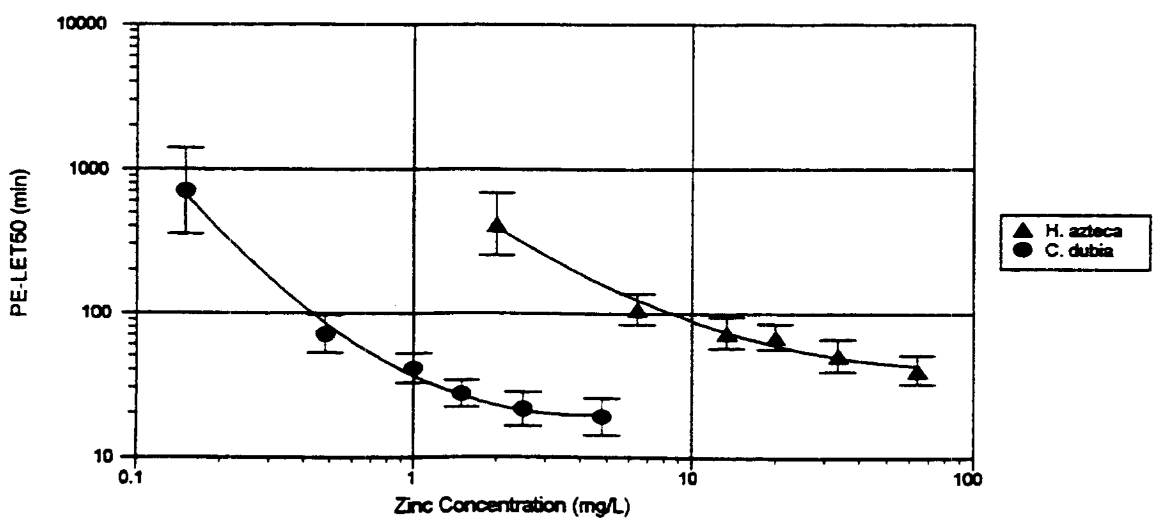
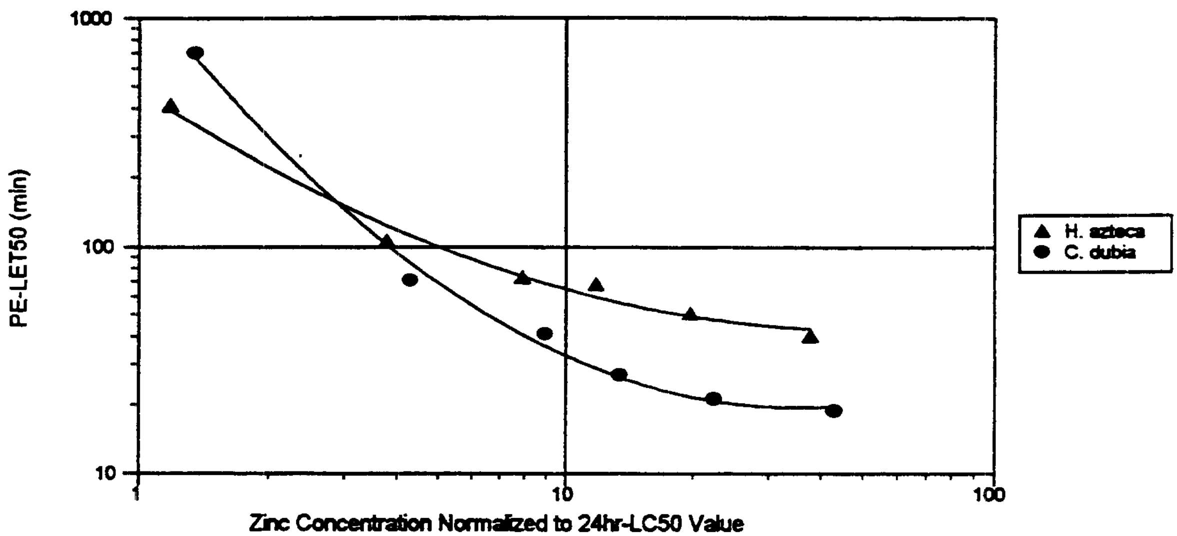


Figure B-21. Comparison of PE-LET$_{50}$ Values for Different Species over a Range of Zn Concentrations Normalized to 24-hr LC$_{50}$ Values



The Zn concentrations were again normalized using the 24-hr LC$_{50}$ values for each species to determine whether observed differences in short-term exposures could be explained by differences in 24-hr LC$_{50}$ values. For the case of Zn exposure (Figure B-21), the 24-hr LC$_{50}$ values do not entirely explain these differences. While the two curves are close to each other, they differ in slope. The disparity in the curves is not as great as it was between *P. promelas* and the other species in Cd exposure experiments (Figure B-19). The difference is probably due to the difference in thresholds. The curves would be altered by the proximity of the 24-hr LC$_{50}$ to the thresholds.

Between Toxicant Comparison of Brief Exposure Tests. Figure B-22 compares the *C. dubia* response to different toxicants. *C. dubia* is most sensitive to Zn exposure and least sensitive to phenol exposure. Notice also that *C. dubia* response to Cd is the most linear within the range observed. *C. dubia* response to Zn showed a curve that decreased in slope as it neared shorter exposure times, indicating the presence of a minimum threshold of exposure time. Phenol exposure strongly exhibited the presence of an exposure duration threshold.

Figure B-23 compares the *H. azteca* response to different toxicants. Only Cd and Zn were tested using *H. azteca*. While *C. dubia* was more sensitive to Zn exposure than Cd exposure, *H. azteca* was much more sensitive to Cd exposure. Zinc exposure to *H. azteca* also showed a curve that implies an exposure time threshold, and Cd exposure again showed a more linear response.

Figure B-22. Comparison of PE-LET$_{50}$ Values for *C. dubia* Exposure to Various Toxicants

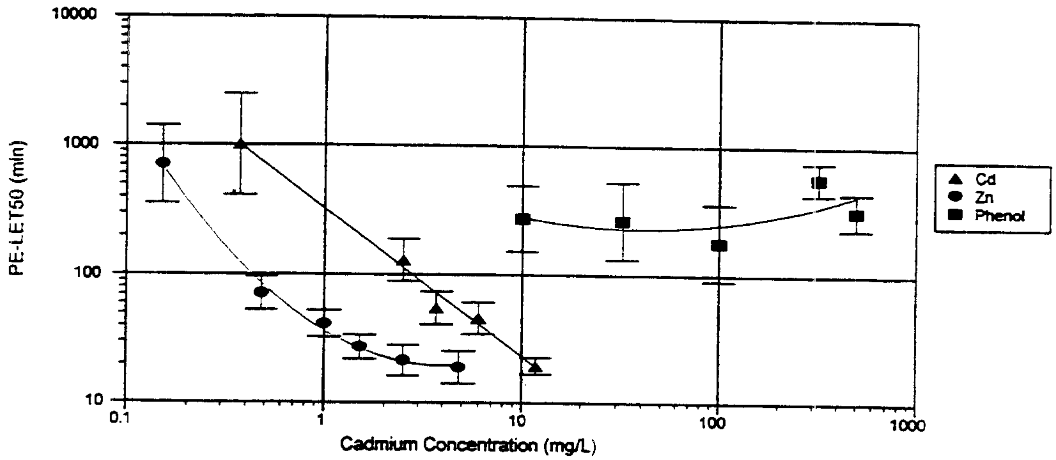
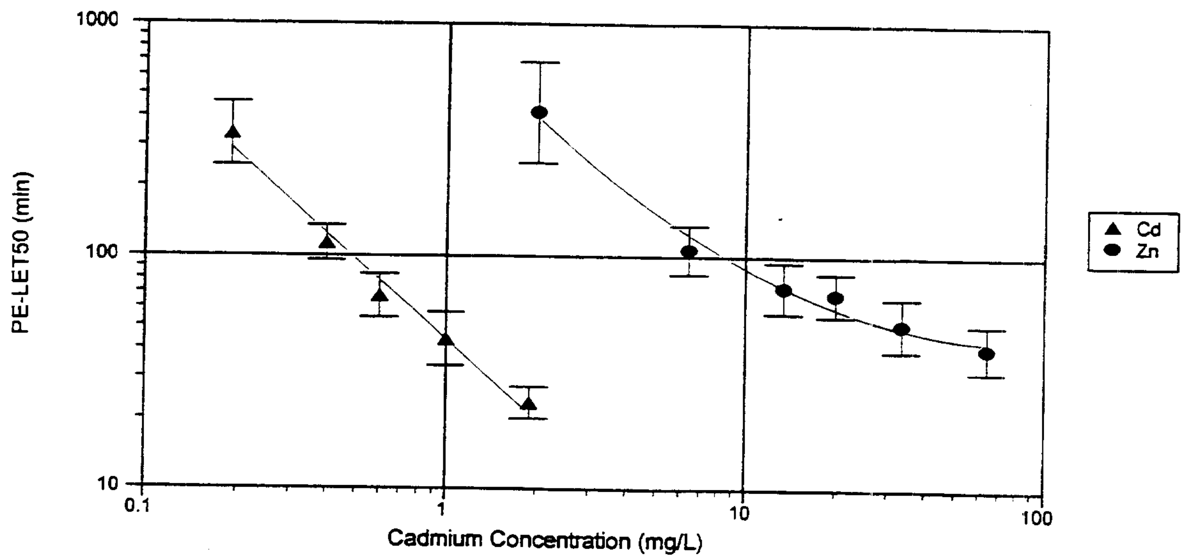


Figure B-23. Comparison of PE-LET$_{50}$ Values for *H. azteca* Exposure to Various Toxicants



Between Stock Culture Comparison of Brief Exposure Tests. Brief exposure tests were performed using stock cultures of *H. azteca* and *C. dubia* from UIUC and the University of North Texas (UNT). Figure B-24 compares the results of brief Cd exposures between the UIUC and UNT stock cultures. *H. azteca* from both cultures were more sensitive to short-term Cd exposures than *C. dubia* from either culture. Within the same species, the UNT stock cultures were more sensitive than were the UIUC cultures. The slopes of the curves are relatively consistent between the different stock cultures and species. The differences in sensitivity between the stock cultures may be due to genetic variability in isolated strains, slight differences in culturing methods or practices, or simply differences in dilution waters between the two locations. The dilution waters used at each location were the waters in which organisms were normally cultured. Hard reconstituted water was used for *C. dubia* at both locations, dechlorinated tap water was used for UNT *H. azteca* stock, and filtered Copper Slough water was used for UIUC *H. azteca* stock. The characteristics of these dilution waters is seen in Table B-7.

Figure B-24. Comparison of PE-LET$_{50}$ Values for Different Stock Cultures over a Range of Cd Concentrations

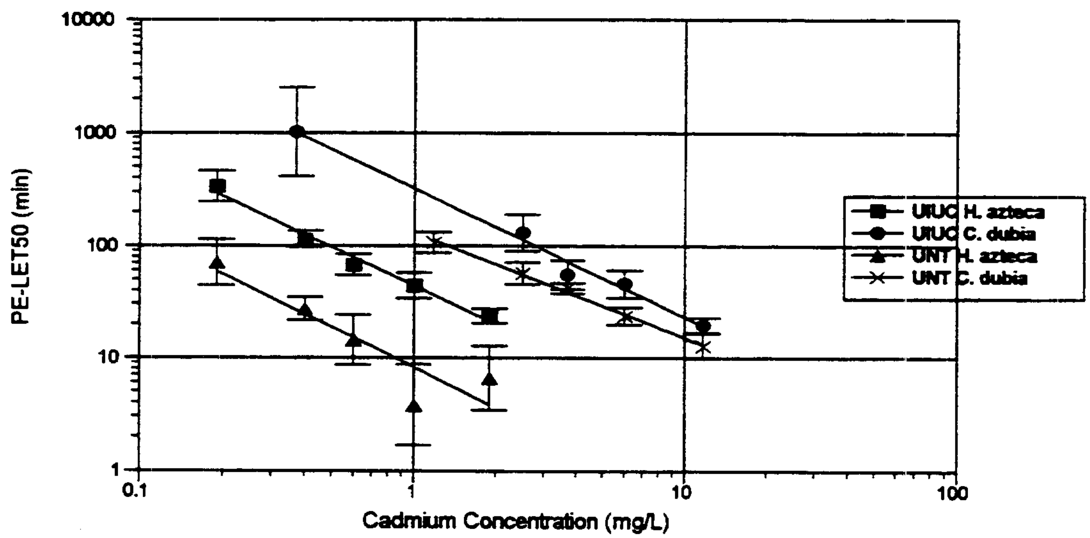


Table B-7. Chemical Characteristics of Dilution Waters Used

Dilution Water	pH	Hardness	Alkalinity
Reconstituted water	7.6 - 8.0	160 - 180	110 - 120
Dechlorinated tap	7.2 - 7.5	120	
Copper Slough	7.2 - 8.8	210 - 260	

Conclusions. Significant effects are indeed seen at very brief exposure times (even at durations of exposure as short as 15 minutes). Also, duration of exposure has a profound effect on the severity of the response. For these reasons, wet weather testing should use exposure times that match the duration of true wet weather exposures to adequately assess effects.

Secondly, there exists a potential for either delayed effects or organism recovery after brief toxic exposure. Delayed effects were seen for *H. azteca*, *C. dubia*, and *P. promelas* exposure to cadmium and zinc. Recovery from immobility was seen after *C. dubia* exposure to phenol. Delayed effects and recovery were even observed for the same contaminant. *C. dubia* experienced delayed mortality after cadmium exposure, yet organisms were able to recover from sub-lethal effects (enzyme inhibition). The potential for delayed effects and recovery indicate that wet weather testing should use methods which incorporate a post-exposure observation period. As comparisons of continuous exposures and pulse exposures with post-exposure observation indicated, measurement of endpoints only at the end of the exposure period can overestimate effects in the case of recovery and underestimate effects in the case of delayed effects.

Different species and even different stock cultures of the same species were seen to have different sensitivities to brief toxic exposures. This finding supports the test battery approach to wet weather monitoring used in this research. A battery of different species and different tests is necessary to adequately assess the effects of wet weather discharges where multiple contaminants and variable durations of exposure are present. In addition, it was also shown that sensitivity rankings done using longer exposure times do not always reflect sensitivity rankings of species exposed for short durations.

The research also found that certain duration of exposure thresholds exist for certain contaminants. A threshold of approximately four hours was necessary to elicit a response to phenol no matter what the exposure concentration. Zinc appeared to approach a threshold as exposure times dropped below 15 min. No exposure duration threshold existed for cadmium. This finding might affect wet weather monitoring, since the toxicity of certain contaminants need not be considered if exposure durations during the event are extremely short. Conversely, the toxicity of certain contaminants not displaying an exposure duration threshold would have to be of concern no matter how brief the duration of exposure.

Effects, such as growth suppression and reproductive impairment, which are generally considered the effects of chronic exposure, can occur after very brief (or acute) exposures. This research concluded that these chronic effects if present were observed on the margins between lethal exposures and no effect levels. Caution should be taken to not overlook effects typically deemed chronic even when brief, acute exposure conditions are present.

Event Toxicity Integration. As the project team examined frequency and duration issues in storm events, it became apparent that it was not possible to characterize toxicity in a storm event using traditional measurement and analytical techniques. Because toxicity stems from both contaminant concentration and the time-scale of exposure, both concentration and duration were critical issues in assessing toxicity in wet weather events. Results of the examination of storm event toxicity found variable toxicity for samples collected sequentially during a storm event. Another need became obvious: to provide a means of integrating the variable toxicity observed during a storm event into an integral measure of storm event toxicity.

The PE-LET_{50}, previously described, can determine a storm event toxicity that incorporates time varying concentrations during the event. This analysis combines PE-LET_{50} test results from samples collected during the event.

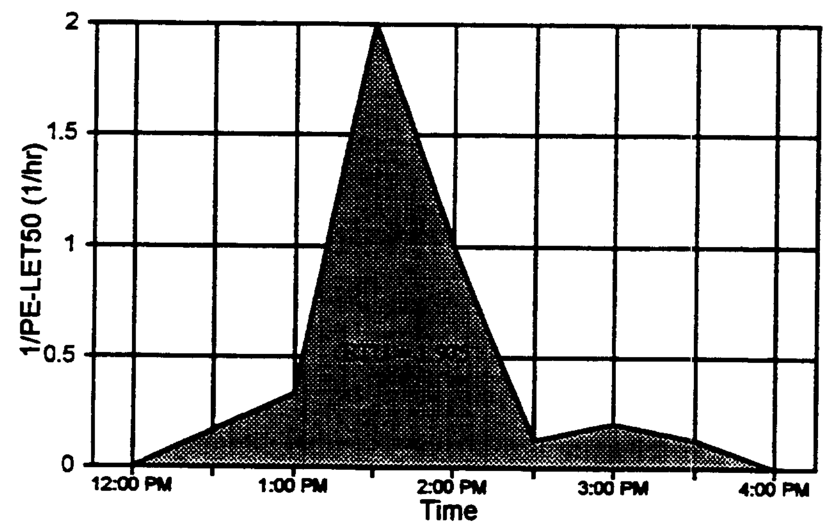
To complete this analysis, PE-LET_{50} values are determined for each sample collected during the event. For samples that showed little toxicity (that is less than 50% effect was measured in screening tests on 100% sample after 48 hours) the PE-LET_{50} for that sample is assigned a value >48 hours. Table B-8 shows example data for samples collected during a hypothetical four-hr episodic pollution event.

Table B-8. Example PE-LET_{50} Data for Event Toxicity Unit Analysis

Time of sample	PE-LET_{50} (hrs)	1/PE-LET_{50} (1/hr)
12:00	>48	0
12:30	6	0.167
1:00	3	0.33
1:30	.5	2
2:00	1	1
2:30	8	0.125
3:00	5	0.2
3:30	8	0.125
4:00	>48	0

The reciprocals of PE-LET_{50} values for individual event samples were then plotted based on the time of sample collection sequentially through the event (Figure B-25). Reciprocals of PE-LET_{50} values were used since PE-LET_{50} values decrease with increasing toxicity. For samples with low toxicity (PE-LET_{50} values >48 hours), the 1/PE-LET_{50} value was set to zero based on the assumption that the contribution to event toxicity from brief exposure to these samples would be negligible (since these samples produced low toxicity after 48 hours of continuous exposure). For consistency, PE-LET_{50} values and event time were plotted using the same units (minutes or hours). The area under the resulting curve was then numerically integrated using the trapezoid rule (Crosswhite, Hawkinson and Sachs, 1976). This integrated area, shown in gray in Figure B-25, then was termed the event toxicity unit (ETU).

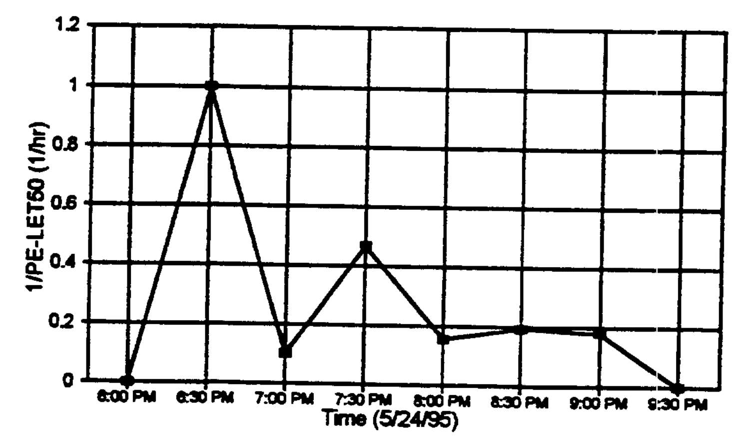
Figure B-25. Example Calculation of an Event Toxicity Unit (ETU)



The ETU is a dimensionless ratio that relates event characteristics to the exposure duration necessary to produce a 50% lethal effect, the PE-LET_{50}. An ETU greater than one indicates that the event would be expected to produce >50% lethality in the test population. An ETU less than one indicates that the event did not produce exposure conditions (magnitude, duration, or combination of both) necessary to produce 50% lethality. In the example given, the ETU was calculated as 1.975. Therefore, the hypothetical episodic pollution event, which lasted for only four hours, was predicted to have a greater than 50% effect. The value of the ETU is that it allows comparison of events that may differ in duration, intensity, and sequence of toxic conditions. Furthermore, the ETU can also be used to compare actual event conditions with reference exposure situations of known toxicity or experimental exposure conditions derived from event characteristics or event modeling.

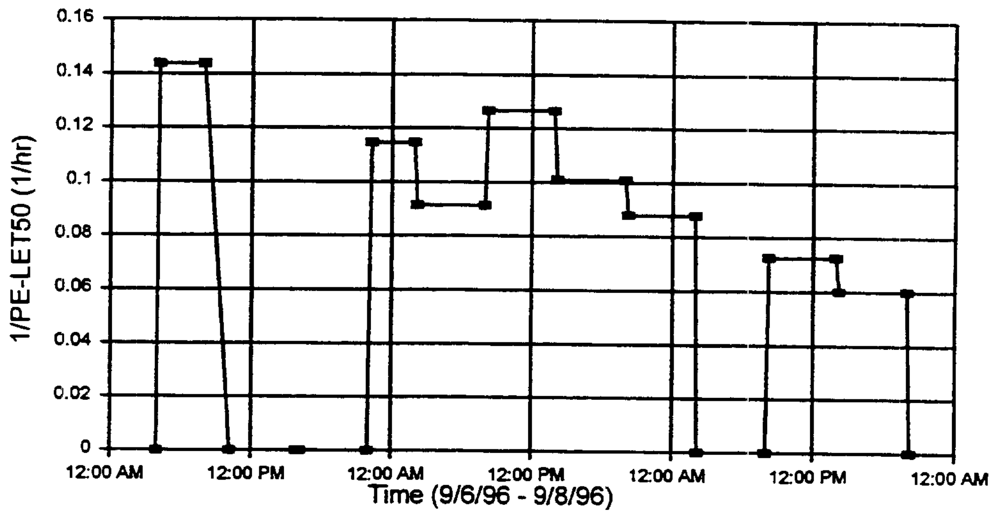
Testing of actual events was conducted for two events. The first was a storm event on 5/24/95 at the Cra site (Fort Worth, Texas). PE-LET_{50} values were calculated for six samples which showed significant toxicity in screening tests. Other samples during the event which showed little to no toxicity in 48 hour screening tests were assumed to have very high PE-LET_{50} values (>48 hrs) and therefore, the 1/PE-LET_{50} value was approximated at zero. The 1/ PE-LET_{50} values were plotted against the time of the event as shown in Figure B-26. The area under the curve was integrated to give a event toxicity unit (ETU) of 1.05. This indicates that the toxicity present during the 5/24/95 storm event at the Cra site was of a sufficient magnitude and duration to cause a greater than 50% lethal effect to *C. dubia*.

Figure B-26. 1/PE-LET_{50} versus Time for 5/24/95 Storm Event at Cra



Toxicity results for the 9/6/96–9/8/96 storm at the Cleveland #35 site appear in Figure B-27. Eight samples were tested for PE-LET_{50} values, while five samples throughout the event were estimated to have 1/PE-LET_{50} values of zero due to low toxicity in screening tests. At this site, the samples were composited over 6-hr periods. The 1/PE-LET_{50} value for each sample was plotted at the beginning and end of the composite period. This method assumes that the toxicity of the composited sample was consistent throughout the composite period. This minimizes toxicity peaks and gives the graph a step-change appearance, rather than the peak-and-valley appearance of the ETU graph for the Cra event. The ETU calculated for the Cleveland #35 event was 4.41. This event surpassed the magnitude and duration necessary for a 50% lethal effect by more than a factor of four. Even though the samples from the Cra event were more toxic than those from the Cleveland #35 site (based on 1/PE-LET_{50} values), the Cleveland #35 event was much more severe due to its longer duration.

Figure B-27. 1/PE-LET_{50} versus Time for 9/6/96 Storm Event at Cleveland #35 Site



Tables B-9 and B-10 show the LC_{50} values for the samples from the Cra and Cleveland #35 sites, respectively. The LC_{50} values for the Cra event showed greater toxicity, the LC_{50} does not reflect the duration of the event and, therefore, does not indicate the overall toxicity of the event.

Influence of Suspended Material on Inhibitory Quotient Test. In undiluted time series samples in which stormwater samples contained marked amounts of suspended material, the *C. dubia* IQ test consistently showed complete inhibition of fluorescence. It is possible that the organisms were feeding on the suspended material rather than the test substrate. If this occurred, any decline in fluorescence levels might not be toxicity related but simply because the organisms have not ingested a consistent amount of test substrate over all treatments. This hypothesis was tested by:

Table B-9. LC_{50} Values for Samples from 5/24/96 Event at Cra Site

Sample Date	Sample Time	LC_{50} (% of whole effluent)
5/24/96	6:30PM	18.58
	7:00PM	35.03
	7:30PM	not determined
	8:00PM	24.88
	8:30PM	12.07
	9:00PM	12.50

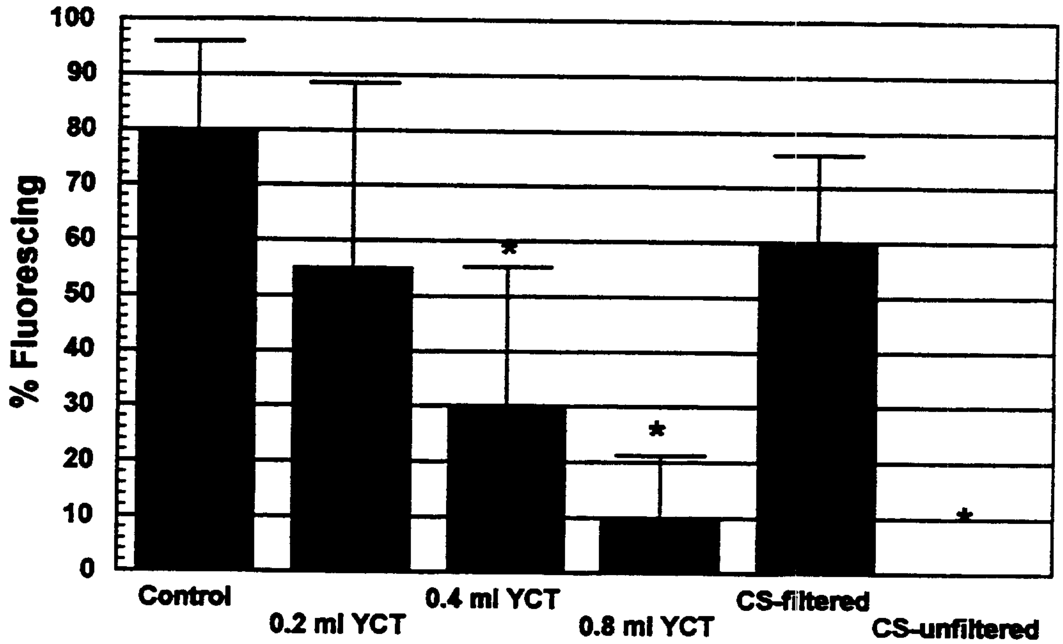
Table B-10. LC_{50} Values for Samples from 9/6/96 Event at Cleveland #35 Site

Sample Date	Sample Time	LC_{50} (% of whole effluent)
9/6/96	4:15AM	22.82
	10:15PM	34.02
9/7/96	2:15AM	39.23
	8:15AM	32.42
	2:15PM	35.36
	8:15PM	35.36
9/8/96	8:15AM	68.04

- Adding varying amounts of yeast-cerophyll-trout food (YCT) mixture into exposure vessels and monitoring changes in the level of fluorescence relative to controls;
- Adding varying amounts of kaolinite into exposure vessels and monitoring changes in the level of fluorescence relative to controls; and
- Comparing fluorescence in filtered and unfiltered stormwater samples.

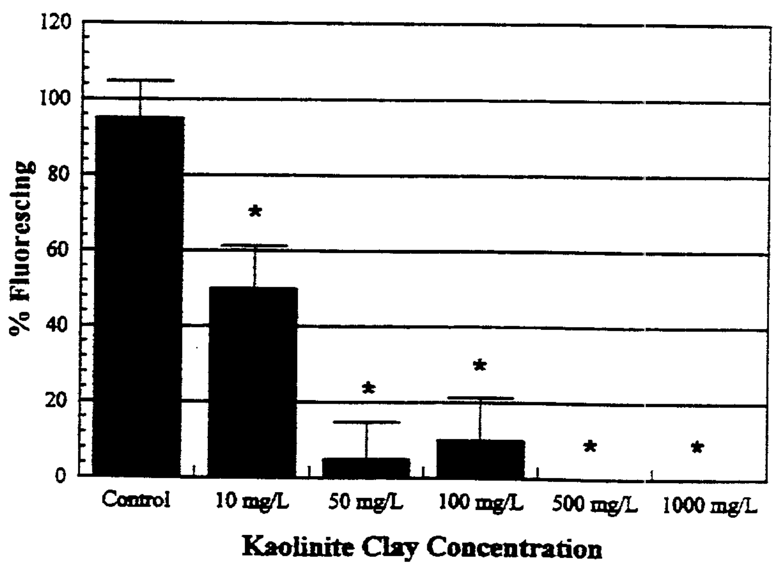
Adding 0.2, 0.4, or 0.8 mL of YCT to test vessels caused a concentration-dependent reduction in the level of fluorescence (Figure B-28). The addition of 0.4 and 0.8 ml YCT significantly reduced fluorescence relative to the control.

Figure B-28. IQ Test Results with YCT Added to Test Solution



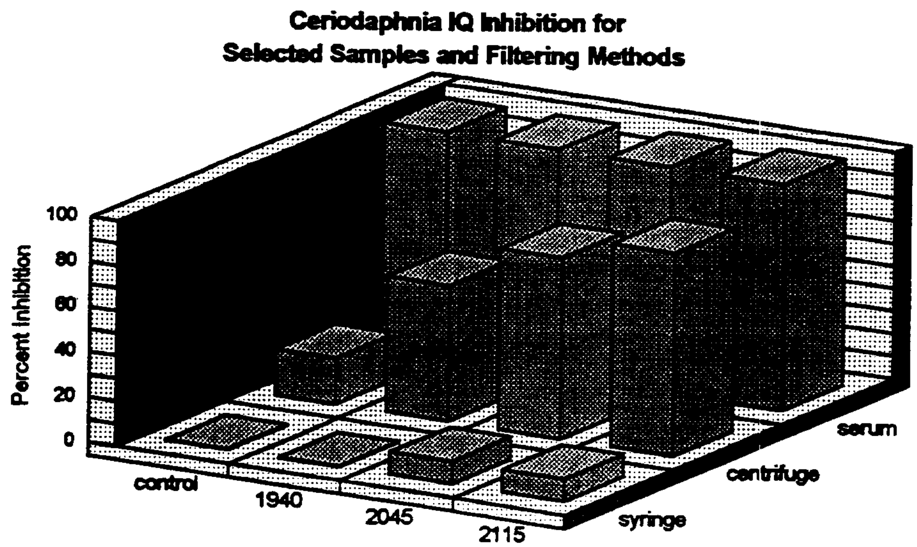
The addition of kaolinite clay to test vessels also showed a concentration-dependent reduction in fluorescence over the range 10 to 1,000 mg/L (Figure B-29). Fluorescence was significantly reduced, relative to the control at 10 mg/L with no fluorescence being evident at concentrations of >500 mg/L.

Figure B-29. IQ Test Results with Kaolinite Added to Test Solution



Comparisons of filtered and unfiltered water samples from the 2/26/96 storm at KLSS (19.40, 20.45, and 21.15) showed that for the IQ test there was a reduction in apparent toxicity with filtration of samples. However, the method of filtration proved to be important, and samples filtered though 0.45-µm membrane filters, Microtox solid phase filters, and centrifuged for 5 min at 5,000 rpm gave different results (Figure B-30). Filtering the sample through a 0.45-µm filter only minimally inhibited fluorescence in *C. dubia* exposed to all samples, whereas differences in inhibition were seen in some centrifuged samples. It is likely that filtering the samples through a 0.45-µm filter removes all the particulate material, but some toxicants might bind to the filter. Centrifuged samples will not be affected in this way and an equilibrium will be established between the water and solid phases. Filtering samples through the blood serum tubes still resulted in complete inhibition which may have been due to the presence of particulates or the leaching of toxic material from the tubes themselves.

Figure B-30. IQ Results for Different Filtering Methods



These findings indicate that all samples containing particulate material must either to be centrifuged prior to the *C. dubia* IQ test, or the test procedure must be modified so that animals were not exposed to particulates during testing. This could be achieved by taking organisms from the undiluted samples after 1-hr exposure and then exposing them to the test substrate in clean water for 15 min. Enzyme inhibition persisted for several hours after short-term exposure to cadmium, so recovery would not be expected during the 15-min exposure to the test substrate in clean water.

Microtox Stimulation/Hormesis. A common finding of Microtox assays of stormwater samples was the presence of stimulation rather than the expected inhibition of light output. Investigations indicated that the stimulation observed could be due to hormesis—a stimulation occurring as a result of exposure to mild toxicity. Hormesis has been documented repeatedly, although it is not necessarily understood. Stebbing (1981) collected numerous examples of hormesis involving a wide range of organisms, including algae, protozoa, vertebrates, and invertebrates. The stressors investigated ranged from heavy metals and organic compounds (including hydrocarbons), antibiotics, and ionizing radiation. The concentration-response curves tended toward a similar U-shaped form where there was a mild stimulation followed by an increase inhibition with increasing concentration.

Analysis of stormwater samples in this study produced a reasonably consistent stimulation in the Microtox assay. Figure B-31 illustrates Microtox results from a storm event sampled on July 4, 1995, at KLSS where the drop in conductivity can be used to show storm event onset and duration. Figure B-32 illustrates the results for all test systems used to evaluate this storm event. All other organisms exhibited an inhibition upon exposure to the storm samples, while the Microtox assay generally indicated stimulation, except in samples taken around the first flush, where reductions in light production of up to 87% were measured (Table 6-3). These results were consistent with data gathered from storm samples as a part of this project.

The consistency of response suggested a more detailed examination of low concentration response with the Microtox assay could identify an increased sensitivity of response not previously reported. A series of studies were initiated with the support of the Microbics Corporation (now Azur Environmental) to evaluate stimulation/hormesis in the Microtox assay. Six metal contaminants (Cd, Cr, Cu, Pb, Ni, and Zn) along with phenol and sodium lauryl sulfate were tested using procedures consistent with screening level testing used in this project. A dilution series of ten dilutions of each contaminant were tested simultaneously at two temperatures (15°C and 23°C). Light readings were recorded at 5, 10, and 20 minutes. Experiments were performed three times for each metal, each using a different lot of reagent. Thirty minutes after each vial of reagent was reconstituted, but prior to performing experiments, a test using a standard phenol solution was performed.

Statistical analysis was performed identifying the 95% double-sided bound of the controls. This was considered to be the natural variability of the test. Only data points occurring outside of this range were considered significantly different from controls. Table B-11 summarizes the results by contaminant and temperature for the contaminants tested, and Table B-12 provides the concentration ranges of stimulation by contaminant and temperature.

Figure B-31. Microtox Assay Results for the July 4, 1995, Storm at Kaufman Lake Storm Sewer

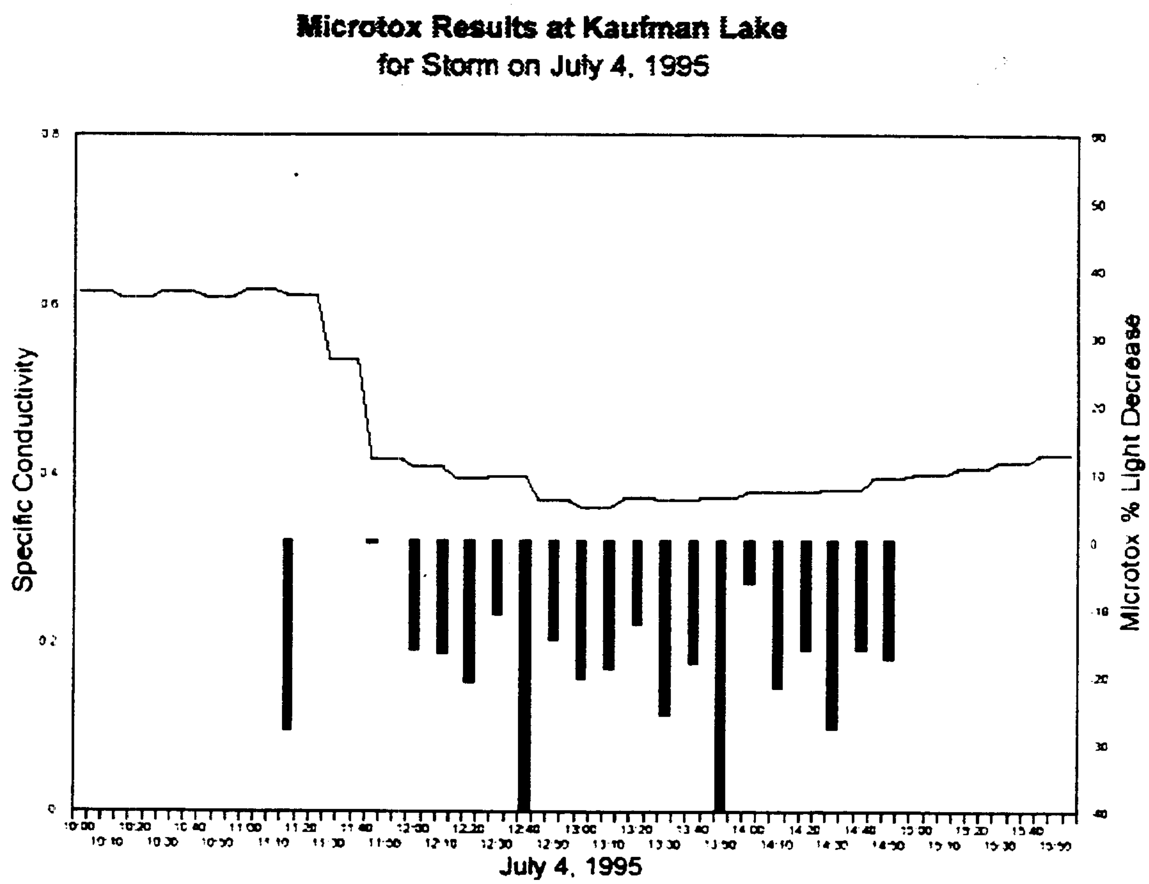


Table B-11. Summary of Hormesis by Contaminant and Temperature

Chemical	Evidence of Hormesis	Temperature of Occurrence
Cadmium	yes	15°C
Chromium	yes	23°C
Copper	no	
Lead	yes	15°C 23°C
Nickel	yes	15°C, 23°C
Zinc	yes	15°C
Phenol	yes	15°C, 23°C
Sodium Lauryl Sulfate	yes	15°C, 23°C

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Figure B-32. Test Battery Results for the July 4, 1995, Storm at Kaufman Lake Storm Sewer

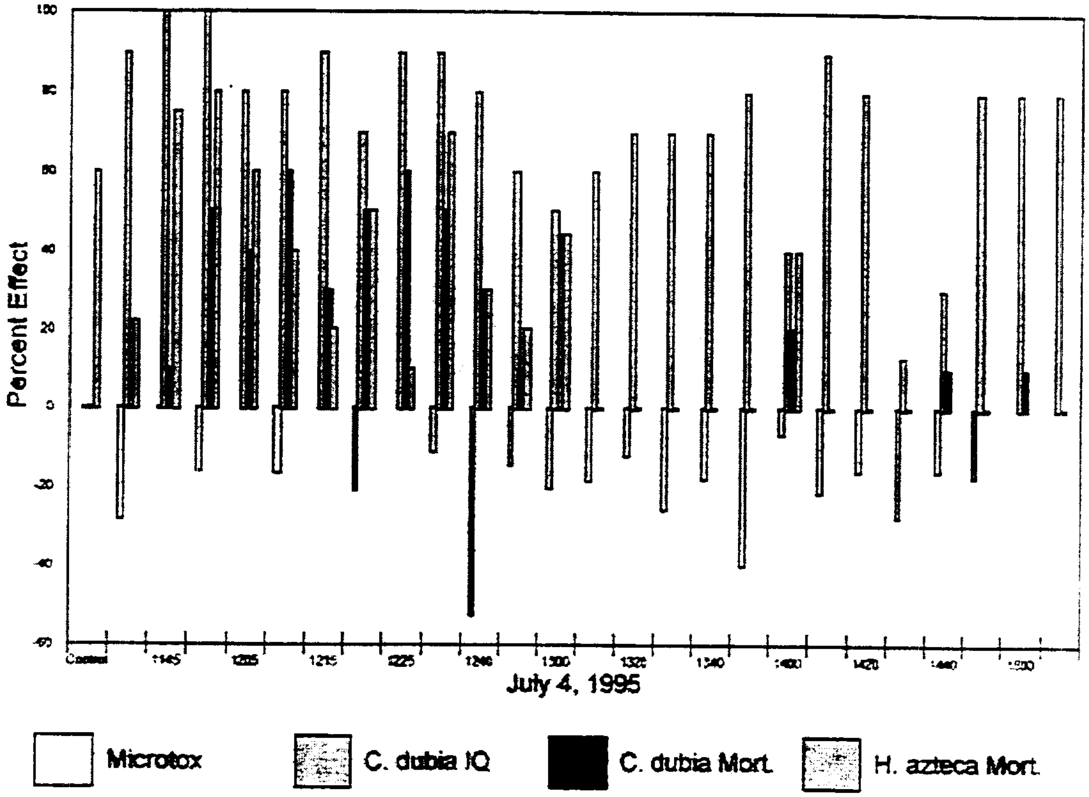


Table B-12. Concentration Ranges of Stimulation by Contaminant and Temperature

Contaminant	Range @ 15°C (mg/L)	Range @ 23°C (mg/L)
Cadmium	0.05, 0.5-2.5	–
Chromium	–	0.1-10.0
Copper	–	–
Lead	0.001-0.01	0.001, 0.05
Nickel	0.01, 1.0	0.1-1.0, 5.0-50.0
Zinc	0.001-0.1	–
Phenol	0.1-0.5, 2.5	0.05-5.0
Sodium Lauryl Sulfate	0.05-0.1	0.0001, 0.001, 0.05-0.5

The experiments supported the conclusion that it is possible to quantify stimulation at low exposure levels, and for several contaminants a concentration-response relationship could be identified for the range of exposure concentrations. It was also apparent from this research that the frequency of occurrence and magnitude of induced stimulation was affected by several factors. Some contaminants produced more stimulation than others, particularly chromium and the organic compounds phenol and sodium lauryl sulfate. When the stimulation levels observed in these experiments were compared with stimulation levels observed in stormwater sampling, no single contaminant produced maximum stimulation levels observed in stormwater (up to 60%). Further testing is needed with binary mixtures and simulated stormwater to determine if such high stimulation levels can be obtained experimentally. It is evident that the presence of certain contaminants in samples at low concentrations may cause stimulation of light production, with inhibition of light production being observed at higher concentrations. This pattern of response needs to be considered when interpreting receiving water toxicity data.

Advanced Screening Methodologies

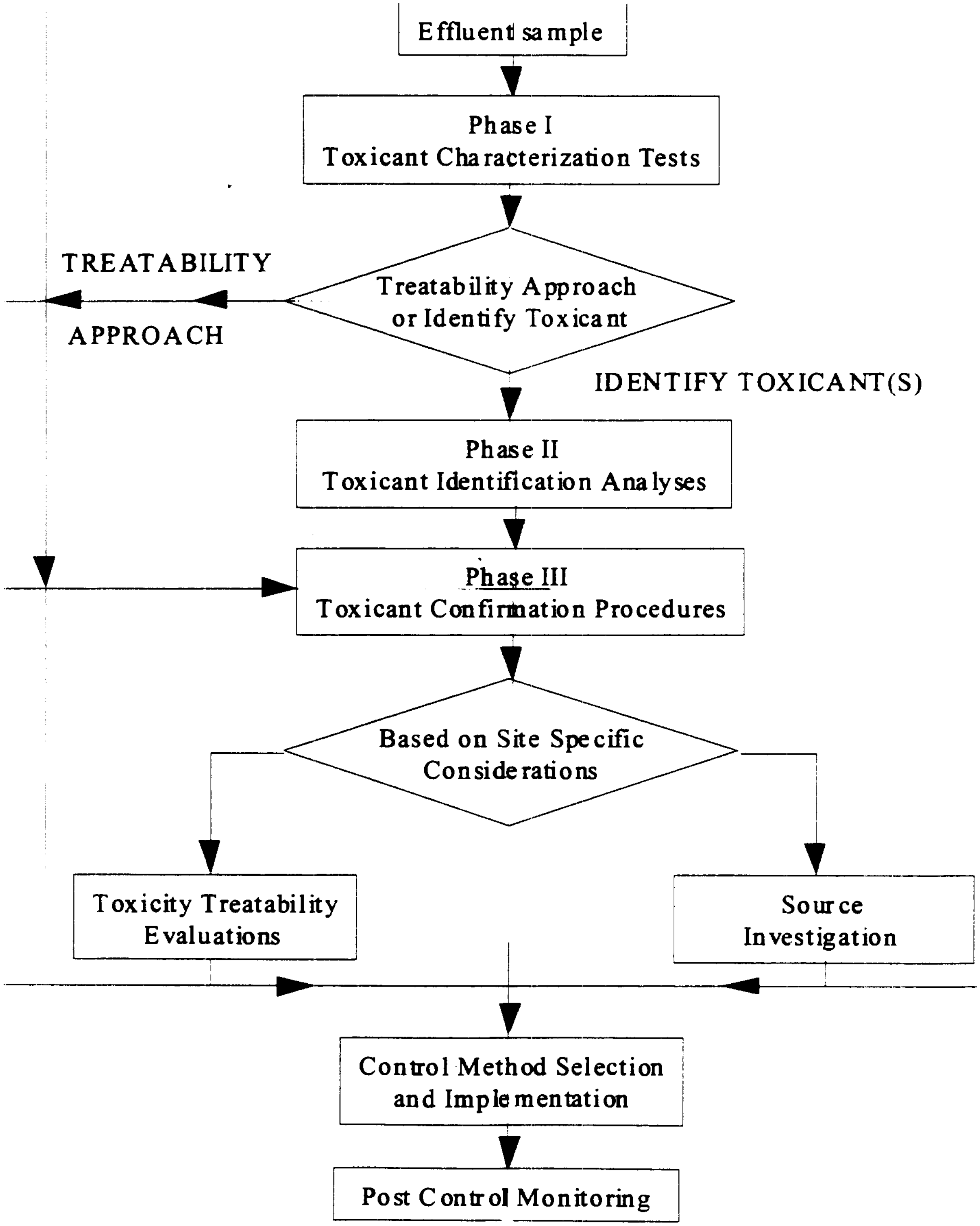
Once high or moderate toxicity has been identified using basic screening tests, then advanced techniques may be used to identify the causative agent(s) or source(s) of the toxicity.

Toxicity Identification Evaluation (TIE) Procedure. The TIE procedure forms part of a Toxicity Reduction Evaluation (TRE); it is designed to identify the cause of toxicity in environmental water samples. It encompasses three phases:

- Toxicant characterization (Phase I), where the objective is to identify the fraction(s) of the sample causing toxicity;
- Toxicant identification (Phase II), where the objective is to identify the toxicant(s) responsible for the observed toxicity;
- Toxicant confirmation (Phase III), where the objective is to confirm the true cause of toxicity.

Figure B-33 provides an outline of the toxicity reduction evaluation procedure and further details on each phase are provided in the relevant US EPA documents (US EPA 1988; 1989a,b).

Figure B-33. Flow Chart for Toxicity Reduction Evaluations (from US EPA, 1988)



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Toxicity characterization involves separating the environmental water sample (and a dilution water control) into a series of fractions using processes such as aeration, filtration (through glass fiber filters) and ^{18}C solid phase extraction, oxidant reduction, chelation with ethylenediamine tetraacetic acid (EDTA), and graduated pH adjustment. This process is designed to identify in which fraction or fractions toxicity is present before toxicity identification and confirmation is carried out to determine the specific toxicant(s) responsible for test responses. The aeration, filtration and ^{18}C solid phase extraction procedures are carried out at three pH conditions: acid (pH 3), unmodified (initial sample pH), and basic (pH 11). Table B-13 summarizes the objective of each fractionation step in the characterization procedure.

Table B-13. Objectives of the Different Fractionation Steps in Toxicity Characterization

Characterization step	Objective
pH adjustment	To provide information on the nature of the solubility, polarity, volatility, stability and speciation of the toxicant(s)
Aeration	To provide information on whether the toxicant(s) is volatile, sublatable or oxidizable
Filtration (glass fiber filters)	To provide information on whether the toxicant(s) is associated with filterable material
^{18}C solid-phase extraction	To provide information on whether the toxicant(s) is a relatively non-polar organic compound or metal chelate
Oxidant reduction addition	To provide information as to whether the toxicant(s) is reduced by the addition of sodium thiosulphate. This step will identify the extent to which toxicity is caused by substances such as chlorine, bromine, iodine, manganous ions, some electrophile organic compounds and some cationic metals
EDTA chelation addition	To provide information as to whether the toxicant(s) is removed by the addition of EDTA. This step will identify the extent to which toxicity is caused by certain cationic metals.
Graduated pH test	To provide information as to whether the toxicity of the toxicant(s) is pH dependent. This step will identify the extent to which ammonia causes toxicity.

The KLSS system consistently shows measurable toxicity during storm events and toxicity characterization (Phase 1 TIE) was carried out on the 1500 sample from the 4/25/96 storm which initially caused 44% light inhibition in the Microtox test and 100% inhibition of fluorescence in the *C. dubia* IQ test. The Microtox test was performed according to US EPA procedure, and the procedures for aeration, filtration through 0.45-μm glass fiber filters, filtration through a 2-ml ^{18}C solid phase column at the three pH values are summarized in Figures B-4 and B-5 for the stormwater and reference water samples. Table B-14 shows the timing of the stormwater sample manipulations and toxicity testing. The fractionation steps were mostly carried out on 4/27/96, and the resulting fractions were analyzed on 4/28/96. The effects of oxidant reduction and EDTA chelation were also assessed on 4/28/96 using the following concentrations of sodium thiosulphate (13 g $Na_2S_3O_3$ per liter stock) and EDTA (37.2 g per liter stock):

Sodium thiosulphate (g L^{-1}): 0, 0.05, 0.1, 0.2, 0.4, 0.6
EDTA (g L^{-1}): 0, 0.05, 0.1, 0.2, 0.4, 0.6

These concentrations were prepared by adding appropriate volumes of the stock solutions to volumes of the stormwater sample. The stormwater sample had a pH of 7.63, while the reconstituted reference water had a pH of 7.36.

Table B-14. Schedule for Conducting Toxicity Characterization on the 1500 Sample from the 4/25/96 Storm at the Kaufman Lake Storm Sewer

Date	Operation
4/25/96	Intra-event stormwater samples collected
4/26/96	Stormwater samples analyzed with Microtox and *C. dubia* IQ test, sample identified for toxicity characterization
4/27/96	Initial Microtox toxicity test Sample manipulations on stormwater and reference water samples: • pH adjustment (pH 3, pH 7.4, pH 11) • pH adjustment/aeration • pH adjustment/filtration • pH adjustment/ ^{18}C solid phase extraction
4/28/96	Microtox toxicity tests on: • Unmodified sample • pH adjusted samples • aerated samples • filtered samples • ^{18}C solid phase extraction samples • sodium thiosulphate addition samples • EDTA addition samples • graduated pH samples

Figure B-34. TIE Procedure for Stormwater Samples

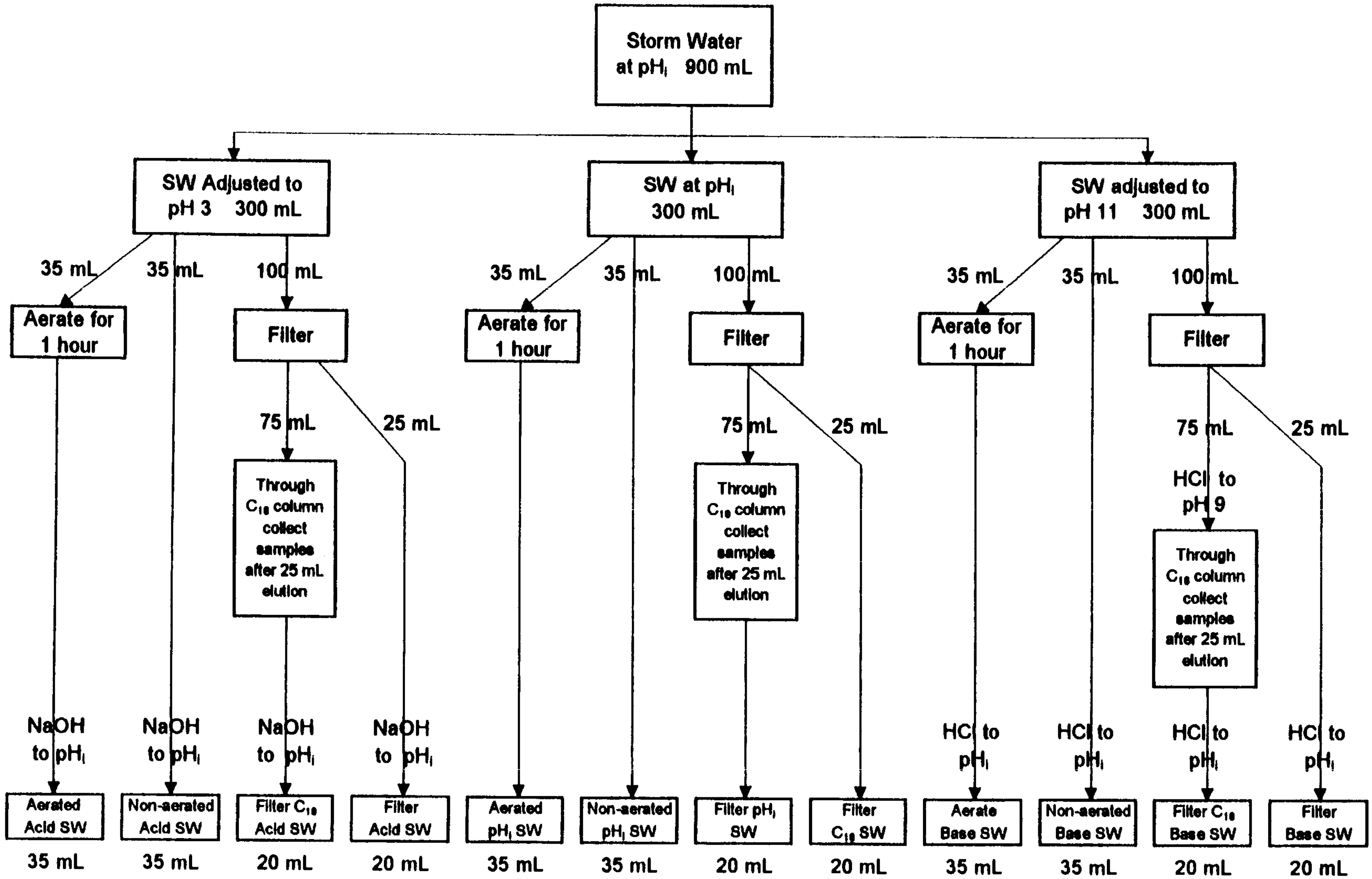

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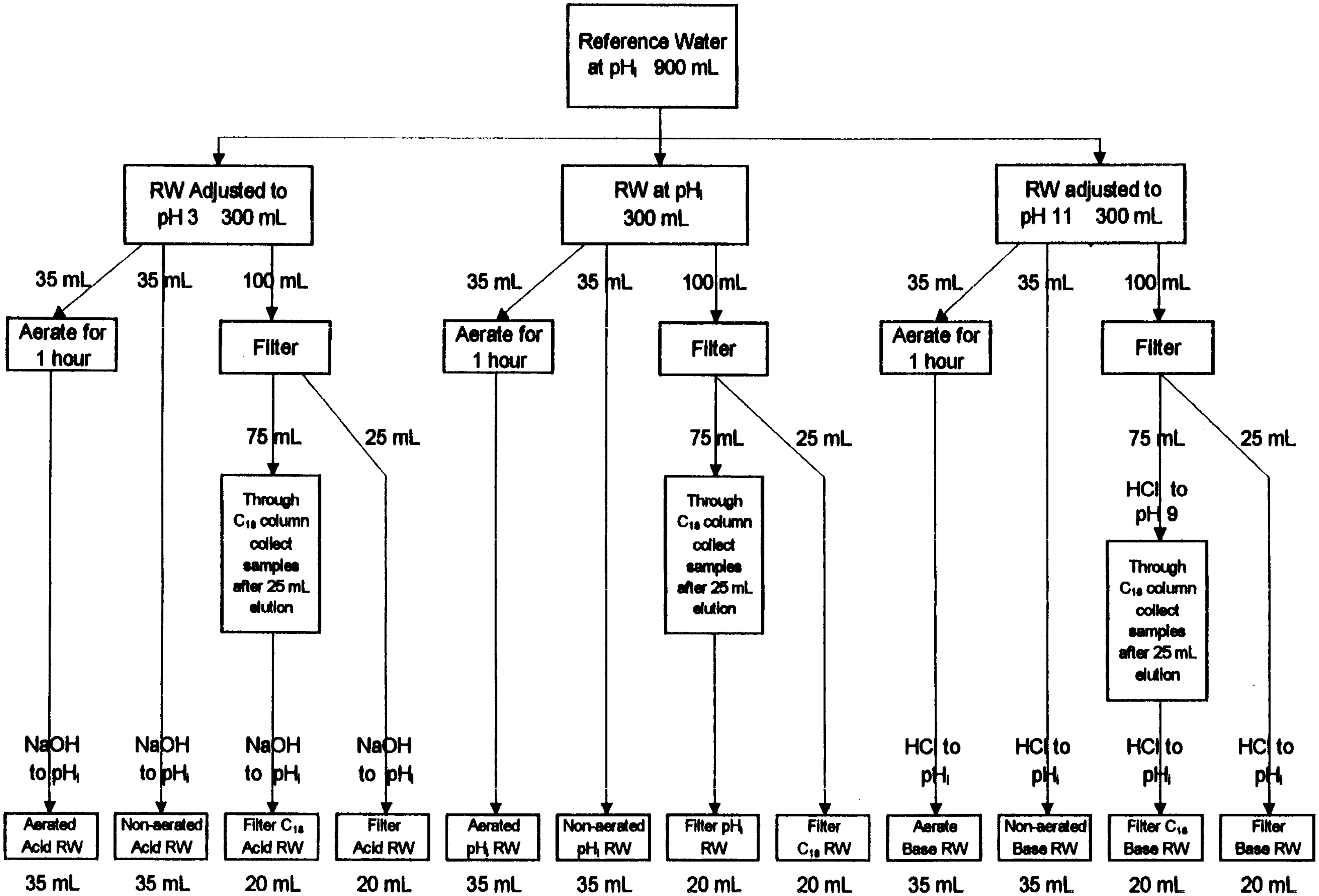
Figure B-35. TIE Procedure for Reference Water Samples



Microtox testing was carried out on undiluted samples and fractions, and light inhibition was measured on three replicates after 5, 10, and 20 minutes. Measurements were made after these different exposure periods since changes in the extent of light inhibition over time can provide additional information on the nature of contaminants present in a sample. For example an increase in light inhibition over time is indicative of the presence of heavy metals such as copper and zinc since these substances require longer exposure times than organics to exert any toxic effects (see Reteuna et al., 1986).

Table B-15 shows the light inhibition in the Microtox test measured in the different fractions of the storm water sample after 20 min exposure relative to the reference water fractions. Testing of the unmodified sample showed that light inhibition declined from 44% on 4/26/96 to 23% on 4/28/96, indicating the presence of non-conservative contaminants. For pH 7 fractions, no reduction in light production was evident after aeration while responses were reduced following the addition of EDTA. On the basis of the data the limited toxicity measured on 4/27/96 was probably due to a combination of volatile materials and metals.

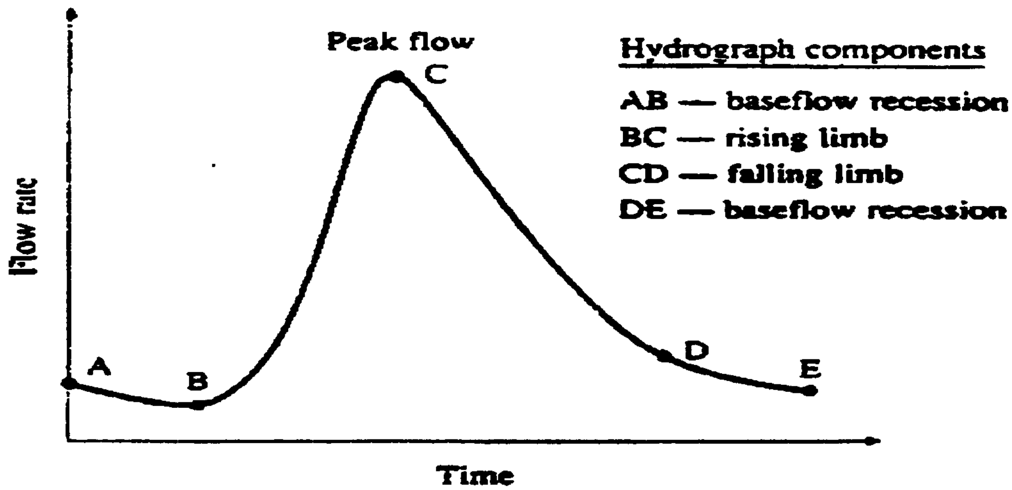
Hydrograph-Based Toxicity Prediction. Literature reports and observations made during field testing on this project, and a general analysis of contaminant/hydrograph relationships suggest that toxicity during a storm related hydrograph should be predictable. To this end, a simple predictive model of site-specific receiving system toxicity associated with storm events was developed. The underlying concept for the development of this model was that it was possible to use regional hydrologic information to describe hydrograph characteristics. Further, it was possible to translate expected contaminant concentration into a toxicity unit (TU), and provide an additive estimate of event toxicity.

The model completes an estimation of a hydrograph from a partial specification of hydrograph characteristics. On the basis of this projection, and estimates of contaminant input, the model then estimates the expected stream toxicity during runoff events. The hydrograph is a function of "total available overland flow supply, subsurface flow, groundwater flow, slope of the overland and stream segments, and geometry of channels" (Bras, 1990). The hydrograph can be separated into two elements, a rising limb and a recession limb (Figure B-36).

Table B-15. Microtox Data for the Toxicity Characterization of the 1500 Sample from the 4/25/96 Storm at the Kaufman Lake Storm Sewer

Fraction	% Light Inhibition in Stormwater Samples Compared to Reference Water Samples		
	5 mins	10 mins	20 mins
Aerated, acid	-2.6	-0.9	-1.4
Non-aerated, acid	-0.7	1.2	-5.6
Filter, acid	-5.9	0.2	5.8
Filter ^{18}C, acid	-11.5	-8.8	-6.9
Aerated, pH7	-19.7	-19.7	-10.5
Non-aerated, pH7	10.4	9.6	7.0
Filter, pH7	10.5	12.3	10.6
Filter ^{18}C, pH7	21.3	18.5	21.3
Aerated, base	-20.3	-20.3	-16.3
Non-aerated, base	-31.2	-29.9	-23.9
Filter, base	13.8	18.4	20.9
Filter ^{18}C, base	-0.2	-1.4	1.4
	% change in response relative to the control		
	5 min	10 min	20 min
0.05 g l^{-1} $Na_2S_30_3$	-3.8	-4.7	-1.9
0.1 g l^{-1} $Na_2S_30_3$	-5.1	-5.7	-4.1
0.2 g l^{-1} $Na_2S_30_3$	-2.1	-2.1	-0.8
0.4 g l^{-1} $Na_2S_30_3$	-0.9	1.0	0.4
0.6 g l^{-1} $Na_2S_30_3$	0	1.4	3.8
0.05 g l^{-1} EDTA	-11.3	-10.4	-10.4
0.1 g l^{-1} EDTA	-10.7	-8.9	-7.8
0.2 g l^{-1} EDTA	-7.8	-8.4	-8.5
0.4 g l^{-1} EDTA	-5.3	-6.8	-5.9
0.6g l^{-1} EDTA	-13.1	-13.5	-14.1

Figure B-36. Example Hydrograph, Illustrating Rising and Falling Limbs



Rising limb characteristics, such as the peak discharge and the time to reach the peak, are dependent on basin geometry and storm event characteristics. The recession limb of a hydrograph may be modeled according to:

$$Q_0 = Q_t K^t \qquad \text{B-1}$$

where t is the length of time between Q_0 and Q_t and K is the recession constant for a region where the units of time are minutes or hours for small basins and days to weeks for large basins (Viessman et al., 1989). Viessman et al. (1989) described the procedure for determining the appropriate value of the recession constant. First, a hydrograph is constructed to determine discharge at the beginning and end of a time interval. Second, these final and initial discharge values for each interval are plotted against other. Finally, a slope is determined as the value for the recession constant for the system. An example of hydrograph analysis is provided in Figure B-37 for a small storm event.

Meybeck et al. (1992) identified how water quality might change as a function of discharge. Figure B-38 illustrates how contaminant concentration might fluctuate with discharge. In the first figure (A), the lines represent the following: (1) A general decrease in concentration with discharge, which

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implies increasing dilution of a substance introduced at a constant rate. (2) Limited increase in concentration generally associated with the flushing of soil constituents. (3) a similar mechanism as curve (2), but a higher discharge causes dilution of the soil runoff water. (4) Increase in particulate matter due to sheet erosion and bed remobilization. (5) A hysteresis loop that is observed when time is introduced as an additional parameter in the sediment-discharge relationship. (6) Water source with a constant concentration, for example Cl^- in rainfall. Figures B and C provide illustrations for change in concentration with time for different, single, storm events. A common component of the single event illustration is the presence of a "first flush" of contaminants (Walling and Foster, 1975). Following the first flush, contaminant concentrations can vary. Concentrations may be low if diluted by storm flows, or show peaks of concentration through time due to different concentration times for different first flush flows in a basin, or increased concentration due to resuspension of previously settled contaminants.

To convert predicted or actual contaminant concentrations to effect estimates the toxic unit (TU) defined by US EPA (1991) was used. A TU is "a measure of toxicity in an effluent as determined by the acute toxicity units or chronic toxicity units measured: and are simply reciprocals of the LC_{50} or the No Observable Effect Concentration (NOEC). In this model, the acute toxicity unit was used.

A number of assumptions were made in model development:

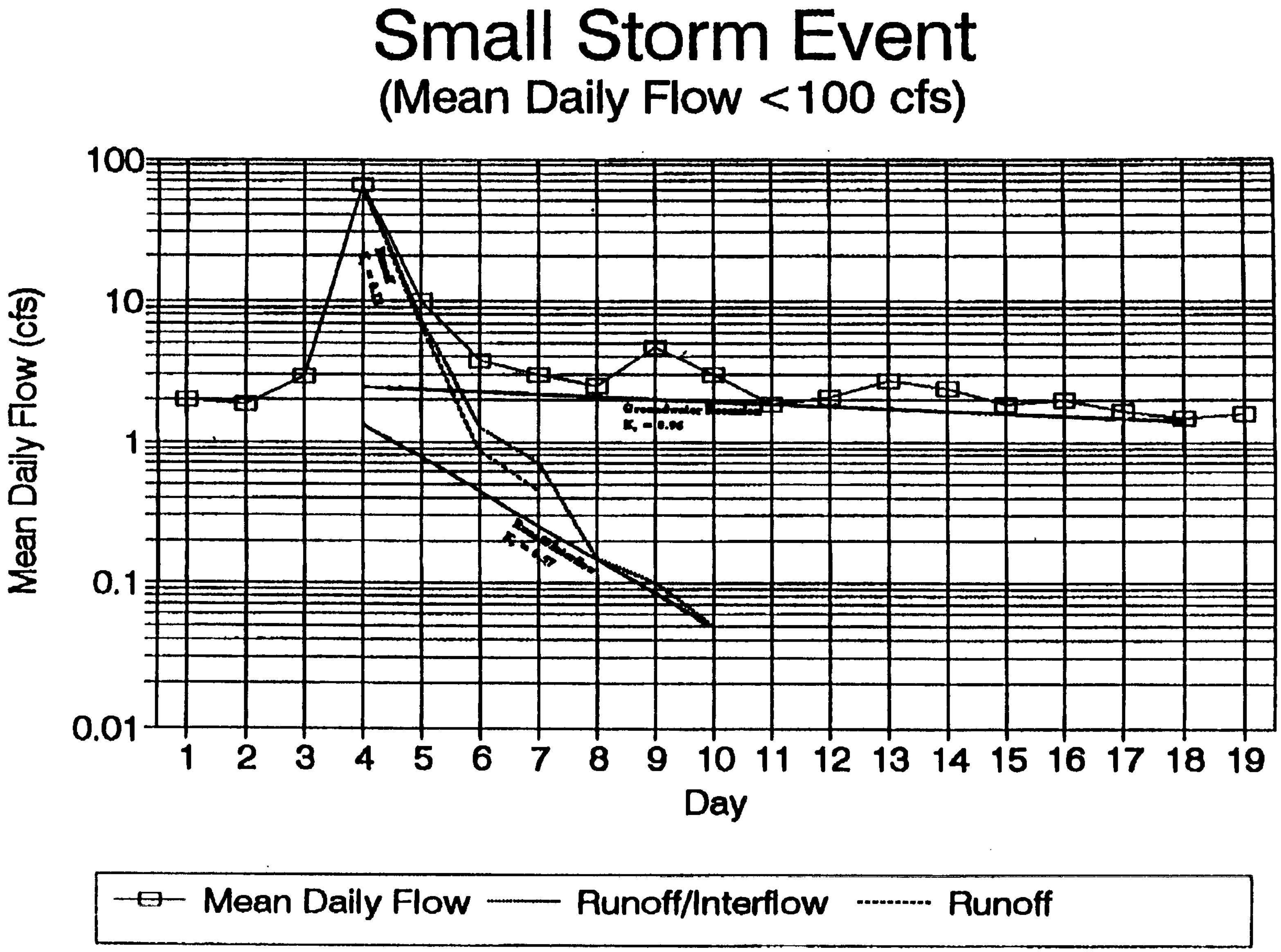
- The rising limb of the model was assumed to be linear.

- The period of hydraulic stress (important is considering the contribution of resuspension to contaminant concentration) was assumed linear along the rising limb and parabolic on the recession limb until an inflection point. Hydrographs are initially convex following the peak and concave after an inflection point. This inflection point is taken to be the end point of the period of hydraulic stress.

- The receding limb of the model following the period of hydraulic stress is based on a recession limb model proposed by Viessmann et al. (1989):

$$Q_0 = Q_t e^{-Kt} \qquad \text{B-2}$$

Figure B-37. Example of Methods Used to Define Recession Constants for Storm Hydrograph



This approach assumes a constant value for the recession constant, which is intended to provide a simplified implementation of K estimation in Appendix A.

- First flush contaminant introduction, expressed in toxic units is assumed to be instantaneous and completely mixed, with a steady state addition continuing with runoff after this pulse. The first flush in this model occurs at 30% of the time to peak.

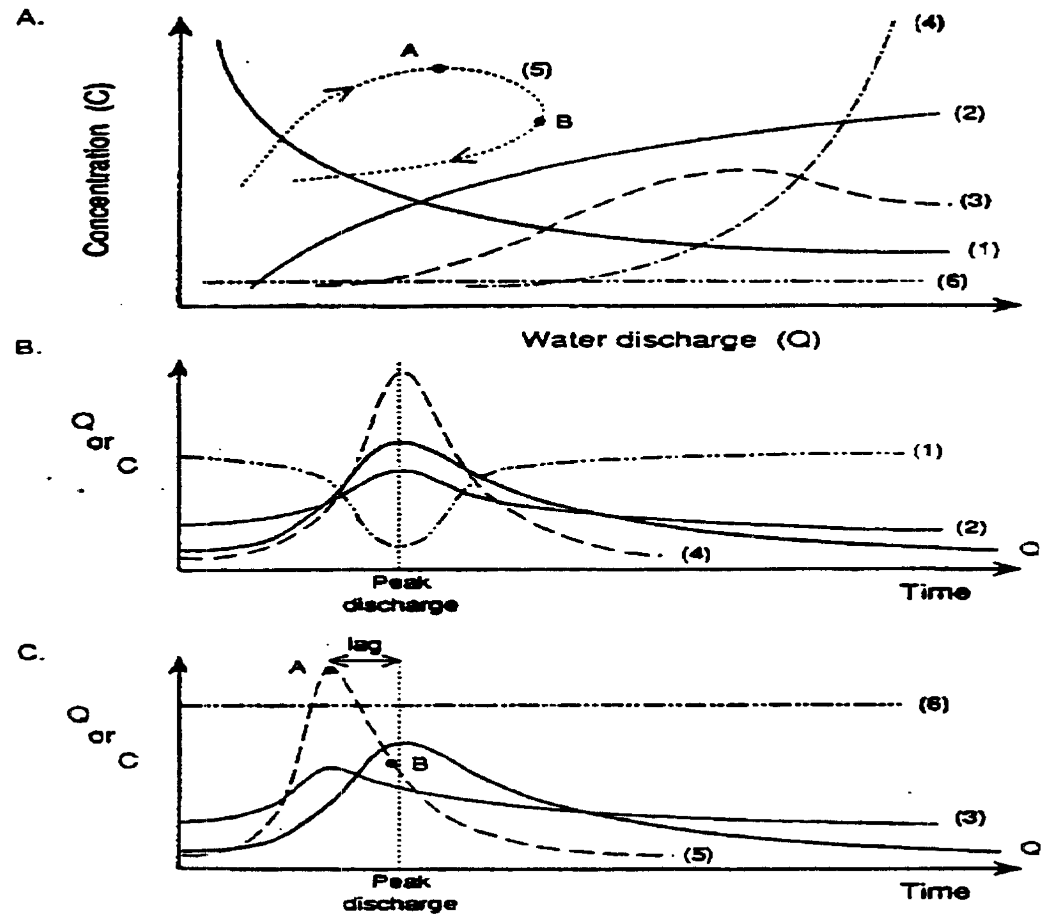
- A steady-state contaminant introduction is assumed to occur during the duration of rainfall. This steady state addition occurs from the time of the first flush through the peak of the hydrograph when direct runoff ceases. The magnitude of this addition is a variable determined by the user, and can be set to zero.

- The toxicity of the stream was assumed to be affected by both increases due to steady state additions and decreases due to dilution and first-order decay. Dilution occurs along the rising limb as discharge (and, therefore, dilution volume) increases. Decay may be set to zero for a conservative contaminant.

The initial model (Lawler, 1994) predicted TU values for only one contaminant where TU values were required as model input. The model was modified (Fitzpatrick, 1995) to allow prediction for five contaminants typical of stormwater discharges (Pb, Cr, Cd, Zn, and Cu), which used the concentration of a contaminant, as an input value, not a specified TU. The revised model calculates a cumulative toxicity using a simple additive assumption. A second revision added the ability to model storm events that produce multiple peaks.

Figure B-39 provides an example prediction for a two-peak storm event. The model was used as a tool to assist in developing a conceptual base for time-scale toxicity analysis. For example, a first flush might produce an initial peak in toxicity followed by a rapid decrease and low levels of toxicity in the remainder of the storm event. Another possible time-scale toxicity scenario finds a second peak of toxicity in a storm event when previously deposited contaminants are resuspended in the water column. When evaluated against storm event monitoring data, the presence of a first flush related toxicity was confirmed. Monitoring also confirmed toxicity later in the hydrograph. The model continues to be useful in providing a "what if" analytical tool to determine what changes are needed in initial assumptions to assist in interpreting possible causes of an observed time-scale toxicity result for a storm event.

Figure B-38. Expected Changes in Contaminant Concentration with Discharge; B and C Are Expected Changes Due to Single Storm Events
(from Meybeck et al., 1992)



Toxicity Prediction. Data collected as a part of this research identified heavy metals as important contaminants in the receiving waters studied (see also Horner et al., 1994). Assessing the toxicity of heavy metals in receiving systems is difficult due to the hydrologic, water quality, and organism variables. To account for some of these complexities, models may be constructed to predict toxic effects due to heavy metal exposures under field conditions. Many toxicity models appearing in the literature are based on first-order kinetics of toxic uptake and depuration. These models commonly represent the organism as a single compartment that can ingest, store, and excrete a toxicant. This is shown in Figure B-40.

Figure B-39. Example TU Prediction for a Two-Peak Storm

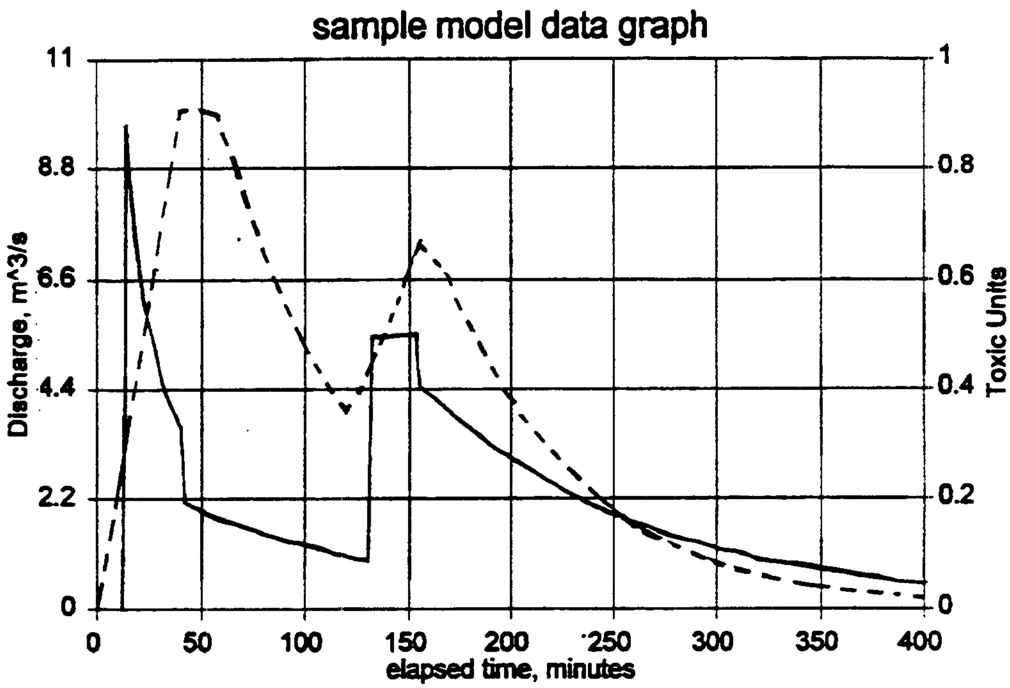
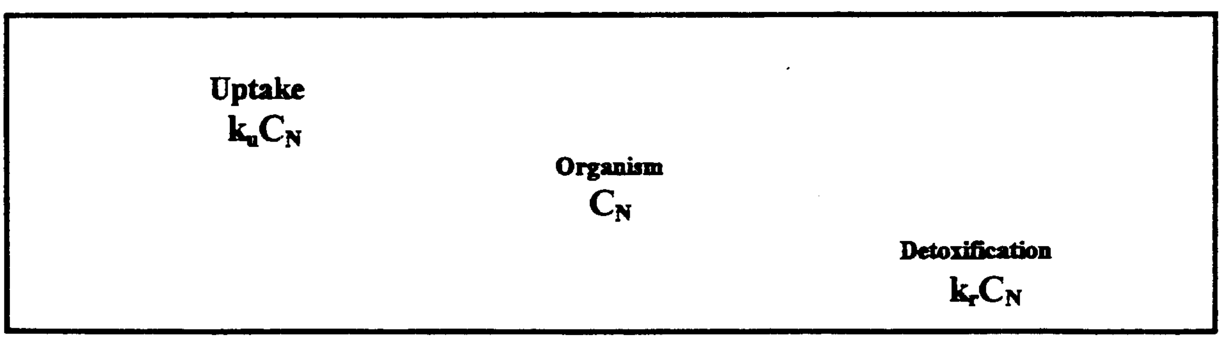


Figure B-40. One-Compartment Organism Representation Used in Some First-Order Kinetics Models



The following equation represents the change in toxicant concentration within the organism:

$$\frac{\delta C_N}{\delta t} = k_u C_w - k_r C_N \qquad \text{(B-3)}$$

where:

C_N	=	Concentration of toxicant in organism (mass of toxicant /mass of organism)
C_w	=	Concentration of toxicant in water (mass of toxicant / volume of water)
t	=	Time of exposure
k_u	=	Toxic uptake rate (volume water / mass of organism / time)
k_r	=	Detoxification rate ($time^{-1}$)

Assuming that there is no toxicant initially present in the organism (i.e., $C_N = 0$ at $t = 0$), Equation B-3 can be integrated to yield the following:

$$C_N = C_w \frac{k_u}{k_r} (1 - e^{-k_r t}) \qquad \text{(B-4)}$$

According to this model, a toxic endpoint, such as mortality, occurs when the tissue concentration reaches a critical concentration, C_D. The time at which this endpoint occurs is t_D. Substituting this boundary condition into Equation B-4 yields the following:

$$C_D = C_w \frac{k_u}{k_r} (1 - e^{-k_r t_D}) \qquad \text{(B-5)}$$

Several studies have used Equation B-5 to predict toxic effects due to time-variant exposures. Hickie et al. (1995) constructed a model to predict toxicity of pentachlorophenol (PCP) to larval fathead minnows, *Pimephales promelas*. In this study, Equation B-5 was rearranged thus:

$$\frac{1}{LC_{50}} = \frac{1}{CBR} \frac{k_u}{k_r} (1 - e^{-k_r t_{50}}) \qquad \text{(B-6)}$$

where:

LC_{50} = Median lethal concentration at time *t* (mass of toxicant / volume of water)

CBR = Median critical body residue (mass of toxicant / mass of organism)

Values for uptake and depuration rates, k_u and k_r, were estimated from each of three separate methods. In the first procedure, body residues of [^{14}C]PCP were measured through time in fish which were exposed to a 24-hour pulse of [^{14}C]PCP followed by a 24-hour recovery period. This provided direct measurements of CBR, k_u, and k_r. The other two methods involved fitting Equation B-6 to toxicity data obtained from continuous PCP exposure tests and the combined results of eight single-pulse exposure tests. The continuous exposure test lasted for 144 hours, while the pulse exposures ranged from 2 to 96 hours. The curve-fitting in each of these two methods yielded values of k_u/CBR and depuration rate, k_r. An uptake rate was estimated by multiplying k_u/CBR by the CBR value obtained from direct measurement of PCP body residues.

Using the kinetics parameters derived from each of the three methods, Equation B-6 was used to predict LC_{50} values for a variety of single and multiple PCP pulse-exposure sequences. Predicted LC_{50}s were compared with actual values recorded for each of these sequences. Out of the three sets of kinetics parameters derived, the best LC_{50} predictions were made using uptake and depuration rates obtained from the eight pulse-exposure tests. The kinetics parameters derived from continuous exposure tests provided the next best LC_{50} predictions. The assumed existence of a critical body residue, CBR, was supported by relatively constant whole-body residues of PCPs measured in dead fish (0.30 mol/kg). The researchers concluded that toxicity models based on Equation B-6 could provide reasonable estimates of toxic effects due to time-variant PCP exposures.

In another study, Meyer et al. (1995) applied Equation B-6 and two other models to predict monochloramine toxicity to the common shiner, *Notropis cornutus*, and rainbow trout, *Oncorhynchus mykiss*. The uptake and depuration rates, k_u and k_r, were estimated from continuous exposure tests involving these organisms and toxicant. A pulse exposure toxicity test subjected common shiners and rainbow trout to repeating cycles of two-hour monochloramine pulses followed by 22-hour recovery periods. The three models considered in this study were used to predict LC_{50} values for each of the first four pulses. Model predictions were then compared to actual experimental results. The researchers found that the best predictions were made using a modified version of Equation B-3:

$$\frac{\delta C_N}{\delta t} = k_u C_w^y - k_r C_N \qquad \text{(B-7)}$$

Assuming $C_N = 0$ at $t = 0$, Equation B-7 can be integrated to yield the following:

$$C_D = C_w^y \frac{k_u}{k_r}(1 - e^{-k_r t_D}) \qquad \text{(B-8)}$$

or:

$$\frac{1}{LC_{50}} = \left[\frac{k_u}{C_{L50}} \frac{(1 - e^{-k_r t_{L50}})}{k_r}\right]^{\frac{1}{y}} \qquad \text{(B-9)}$$

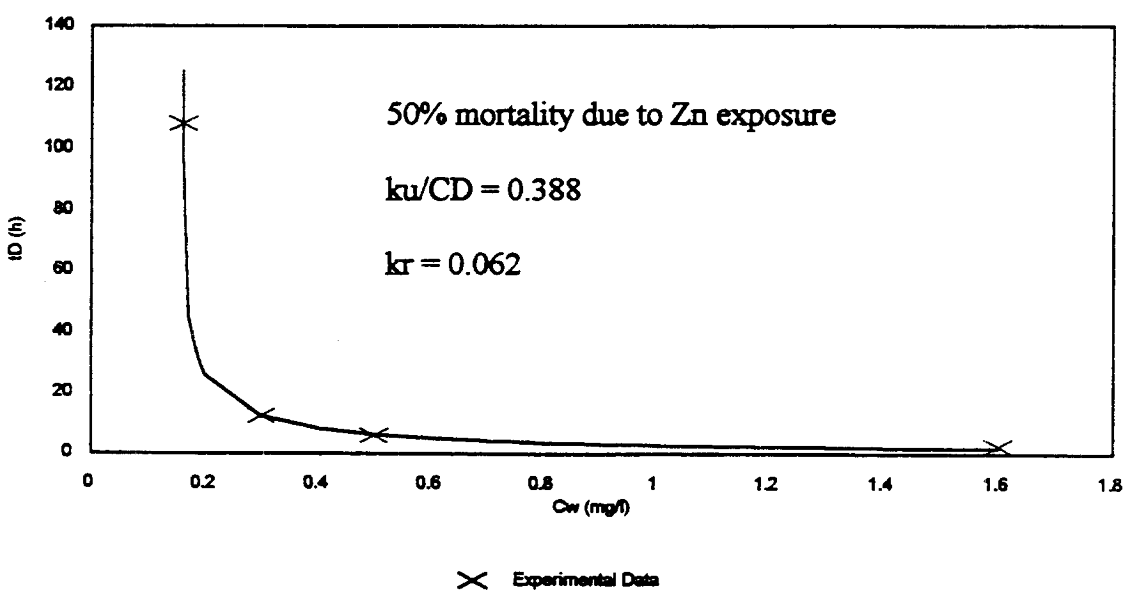
Using values of y = 1.557 and 1.342 for common shiners and rainbow trout, respectively, the predicted pulse CL_{50}s were all within 50% of the observed LC_{50} values.

To evaluate these possible models of heavy metal toxicity, toxic effects due to heavy metal concentrations were predicted using a single compartment first-order kinetics model. The procedure for developing this model is based on the work of Mancini (1983) who applied Equation B-3 to predict organism mortality when exposed to time-variant contaminant concentrations. As previously described, Equation B-3 can be integrated and rewritten as:

$$\frac{1}{C_W} = \frac{1}{k_r}\frac{k_u}{C_D}(1 - e^{-krt_D}) \qquad \text{(B-10)}$$

Equation B-10 contains two unknown parameters: the detoxification rate, k_r, and uptake coefficient, k_u/C_D, which can both be estimated from laboratory tests. Using a series of single-metal concentrations, values of C_w and t_D can be obtained by monitoring organism mortality under continuous exposure to a contaminant. The two unknown parameters may then be obtained by fitting Equation B-10 to experimental data as illustrated by Figure B-41:

Figure B-41. Curve Fitting to Obtain k_u/C_D and k_r Values from Experimental Data



Mancini (1983) assumed that a population of organisms can be divided into sensitivity levels, which are defined by survival-time variations occurring when the population is continuously exposed to the same metal concentration. Each sensitivity level of organisms is assumed to have common response characteristics to a toxicant. For example, if a population of organisms is continuously exposed to a range of metal concentrations, the first 10% of organisms that die in each metal solution would constitute the 10% sensitivity level. Because organisms of different sensitivity levels are assumed to possess different response characteristics, each sensitivity level has different toxic uptake and depuration rates. Thus, curves such as the one shown in Figure B-41 can be developed for each sensitivity level. Having obtained values of uptake and depuration coefficients, k_r and k_u/C_D, for each sensitivity level, the model may be used to predict toxic effects due to time-variant exposures. Using the following boundary conditions:

at $t = t_1$, CN $C_{N(t1)}$

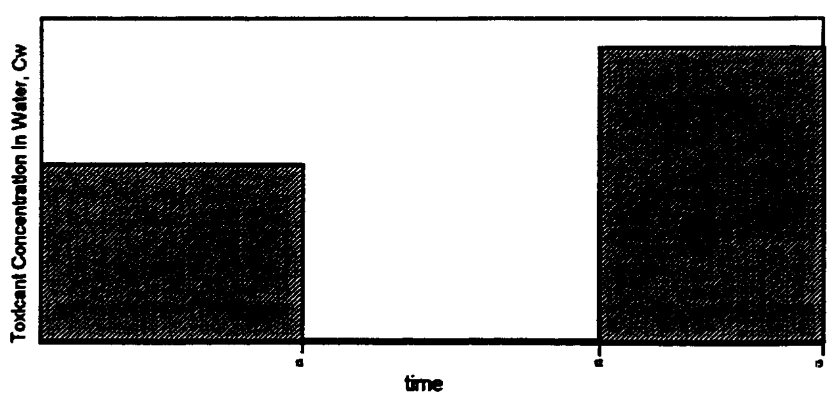
at $t = t_2$, CN $C_{N(t2)}$

Equation B-3 can be integrated to yield the following:

$$\frac{C_{N(t2)}}{k_u} = \frac{C_w}{k_r}\left(1 - e^{-k_r(t2-t1)}\right) + \frac{C_{N(t1)}}{k_u} e^{-k_r(t2-t1)} \qquad \text{B-11}$$

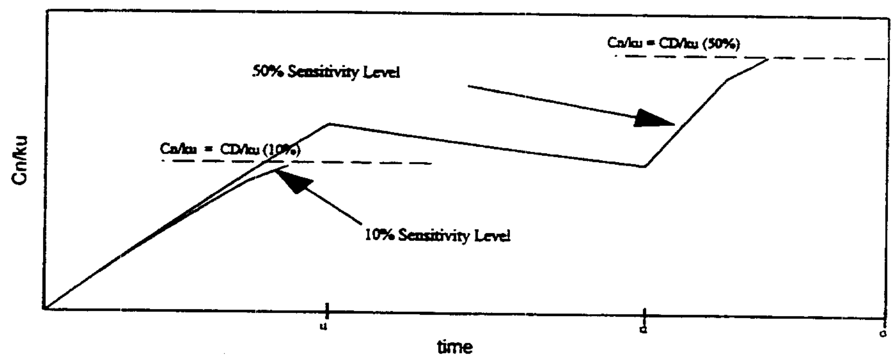
This equation represents the tissue concentration of a toxicant that results from an initial tissue contaminant concentration of $C_{N(t1)}$, a water contaminant concentration of C_w, and an exposure time of $(t_2 - t_1)$. For time-variant exposures (Figure B-42) Equation B-11 may be solved for each time interval over which C_w is constant.

Figure B-42. Example of a Contaminant Concentration Profile



Organism mortality for a given sensitivity level would occur when $C_{N(t2)}/k_u$ equals or exceeds C_D/k_u. The following series of graphs illustrates the use of the model. Figure B-43 displays a contaminant concentration profile through time. Using this profile, Equation B-11 may also be solved at the end of each time interval of constant C_w (i.e., at t_1, t_2, and t_3). Using uptake and depuration coefficients, k_r and k_u/C_D, corresponding to each sensitivity level, profiles of $C_{N(t2)}/k_u$ may be plotted through time. For a particular sensitivity level, each calculated value of $C_{N(t2)}/k_u$ is compared to the corresponding lethal tissue concentration of zinc, C_D/k_u, which is obtained from the model calibration discussed above. If $C_{N(t2)}/k_u$ exceeds C_D/k_u, mortality is assumed to occur in that sensitivity during that particular time-step. This is shown in Figure B-43.

Figure B-43. Calculated C_N/k_u Values for 10% and 50% Sensitivity Levels



By dividing $C_N(t2)/k_u$ by C_D/k_u at the end of each time interval, values of $C_{N(t2)}/C_D$ may be calculated for each interval. These represent the percent lethal tissue concentration (PLTC) for the *n%* sensitivity level at the end of each time interval:

$$(PLTC)_{n\%} = \left(\frac{C_{N(t2)}}{C_D}\right)_{n\%} * 100\% \qquad \text{B-12}$$

Mortality within the *n%* sensitivity level occurs when $(C_{N(t2)}/C_D)_{n\%} = 1$. For the concentration profile shown in Figure B-42, the following data are generated, Figure B-44. Mortality within the n% sensitivity level implies that a cumulative total of *n%* of the population have been killed due to the concentration profile. The percent population survival corresponding to the profile shown in Figure B-44.

Figure B-44. PLTC Values for the 10% and 50% Sensitivity Levels

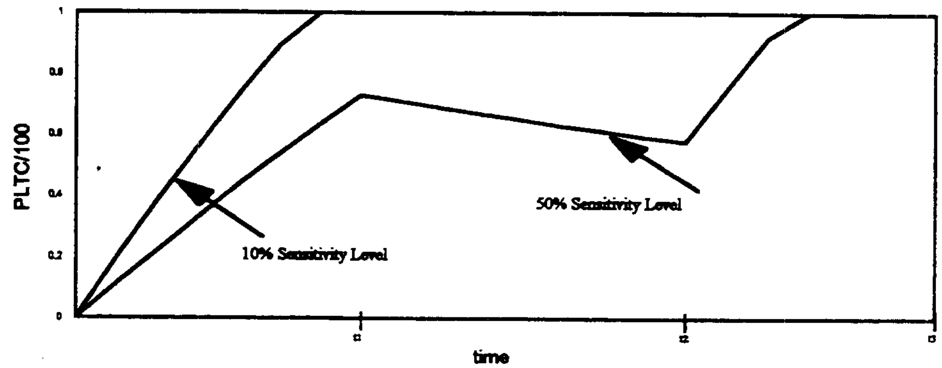
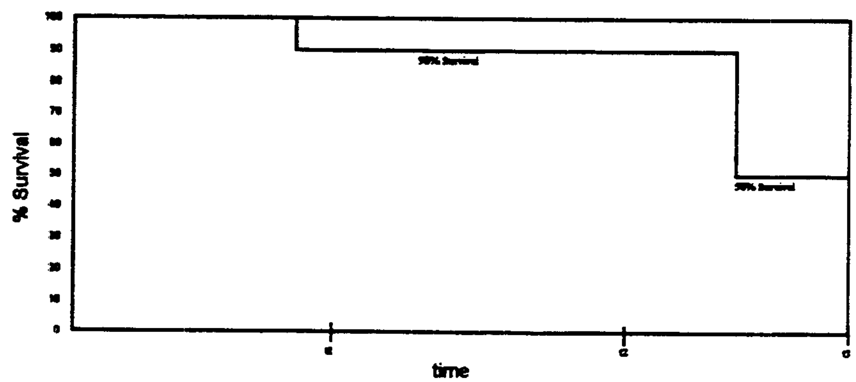


Figure B-45. Population Mortality Predictions Based on PLTC Values



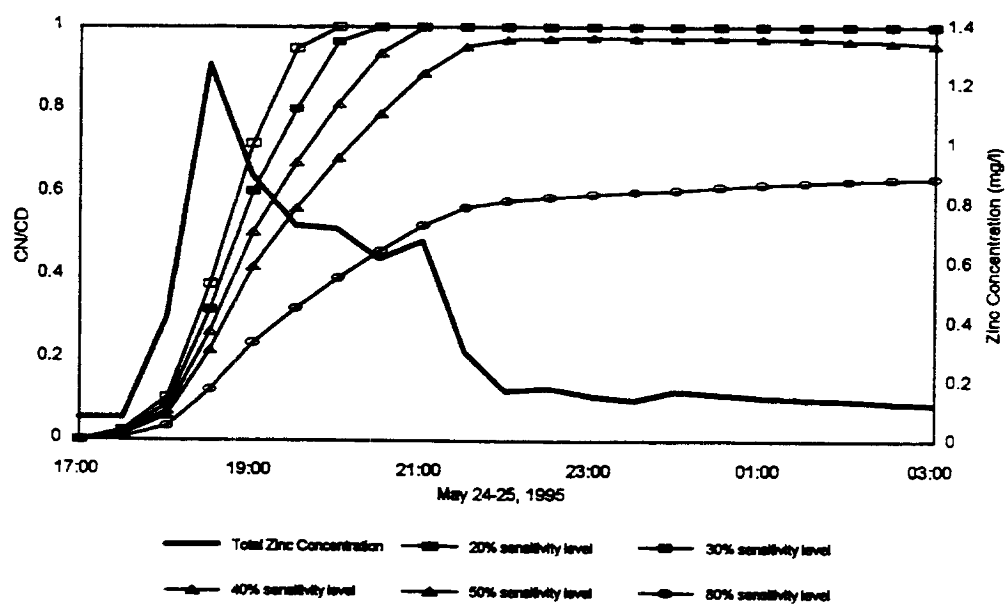
The model illustrated above was used to predict toxic effects of time-variant zinc concentrations to *Ceriodaphnia dubia* and *Vibrio fischeri*. Zinc concentrations were measured at discrete times. Therefore, Equation B-11 was modified to consider an average zinc concentration between every two measurements:

$$\frac{C_{N(t2)}}{k_u} = \frac{C_{w(t1)}+C_{w(t2)}}{2}\frac{1}{k_r}\left(1-e^{-k_r(t2-t1)}\right)+\frac{C_{N(t1)}}{k_u}e^{-k_r(t2-t1)} \qquad \text{(B-13)}$$

Equation B-13 was solved for each time interval between zinc concentration measurements. Values of C_w were obtained from dissolved or total zinc profiles measured at each of the Fort Worth sites. The depuration rate, k_r, for each sensitivity level was calculated in the model calibration discussed above. For each storm event and site examined, t = 0 corresponded to the time at which the first water sample was collected during the storm. The tissue concentration of zinc at t = 0, $C_{N(0)}/k_u$, was assumed to be zero. After the initial time step, values of $C_{N(t1)}/k_u$ were obtained from the solution of Equation B-13 for the previous time interval. Since all variables on the right side of Equation B-13 were known, $C_{N(t2)}/k_u$ could be calculated at the end of each time interval. Equation B-13 was solved for each sensitivity level using the Quattro Pro 6.0 software package. This spreadsheet compared each calculated value of $C_{N(t2)}/k_u$ to the corresponding lethal tissue concentration of zinc, C_D/k_u, to determine if mortality had occurred within the sensitivity level.

The model developed can be used to predict toxic effects resulting from time-variant zinc concentrations. From the model predictions listed above, potential zinc toxicity can be compared among the field sites, and toxicity associated with both dissolved and particulate-phase metals may be assessed. To test this application, the model was applied to data obtained from the Fort Worth field campaign in May, 1995. The model predicts significant zinc toxicity at the Cra site based on predicted total zinc accumulation, Figure B-46. These predictions are supported by toxicity tests which were performed on these samples, Figure B-47.

Figure B-46. Predicted Total Zinc Accumulation in *Ceriodaphnia dubia* at Cra During the May 24, 1995, Storm



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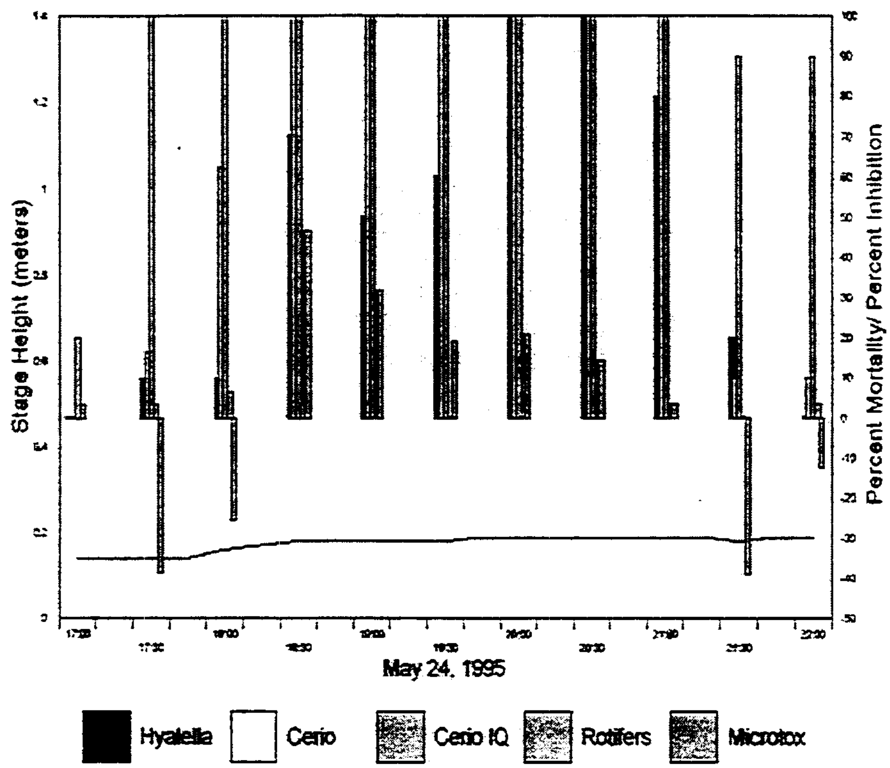
In the test battery *C. dubia* mortality was 100% for samples collected from 1830 through 2100 and the *V. fischeri* light inhibition ranged from 10% to 50% for this same period. These results are also consistent with the ETU determination that found a value of 1.05, which would indicate a highly toxic event.

In contrast to the finding for the Cra site described in Figure B-47, the model predictions indicate that zinc concentrations measured at Sycamore Creek, Eastern Hills, and Pylon will not cause toxic effects in populations of *Ceriodaphnia dubia* or *Vibrio fischeri*. These predictions are supported by toxicity test for *C. dubia*, where low numbers of mortalities (= 20%) were observed in samples collected from these sites. Microtox tests involving *V. fischeri* also indicate relatively low toxicity in these samples; light inhibition was observed in only a few samples, and this inhibition never exceeded 30%.

Although the toxicity tests appear to support model predictions, caution is advised when comparing these two data sets. The model predictions are based on time-variant zinc concentrations, while organisms in the toxicity tests were continuously exposed to relatively steady-state water quality conditions. Another major difference between the data sets is that the model considers only the effects of zinc concentrations, while the toxicity test results are influenced by multiple contaminants, such as copper and lead concentrations, which were observed in each of these samples.

Bioavailability is a critical factor determining the toxicity of metal concentrations within a receiving system (Horner et al., 1994). Bioavailable metals are associated primarily with the dissolved phase. Current heavy metal regulations, however, are based on total metal concentrations (Paulson and Amy, 1993). Because of this emphasis on total concentrations, the model was used to predict toxicity due to both dissolved and total zinc concentrations. By comparing the values shown in different tests it was found that the maximum predicted zinc accumulation in *C. dubia* is between 1.57 and 3.00 times greater for total concentrations than for dissolved concentrations. For *V. fisheri*, the maximum total zinc accumulation is between 1.32 and 2.95 times greater than the maximum dissolved zinc accumulation. These large differences suggest that current zinc regulations are over conservative, since only a portion of the total metal concentration may contribute to bioaccumulation and eventual toxic effect.

Figure B-47. Results of Toxicity Test Battery for the May 24, 1995, Storm at Cra



As with any model used to predict real-world phenomena, the toxicity model presented in this paper is subject to a variety of assumptions and limitations. These should be thoroughly understood before applying the model or interpreting its predictions. The equation governing this toxicity model is based on first-order kinetics of toxicant uptake and depuration. This equation assumes that the organism is a single compartment that accumulates the toxicant at a rate proportional to the contaminant concentration in the surrounding water. The rate of pollutant removal, or depuration, is assumed to be proportional to the tissue concentration of the toxicant. These assumptions might not accurately represent actual uptake and depuration mechanisms of an organism in the receiving system. For example, as a metal concentration in water increases, the uptake rate could decrease due to a reduced feeding rate or temporary immobilization of the organism (Luoma and Carter, 1991). In addition to contaminant concentrations in the organism and surrounding environment, water quality characteristics, such as pH or temperature, can also influence toxicant uptake and depuration rates. The effects of water quality properties are not incorporated in the model.

Another important assumption for the model is that a toxic effect occurs only when the contaminant reaches a critical concentration within the organism. This implies that an organism can completely recover from a contaminant exposure as long as the accumulated toxicant remains below the critical value. Such an assumption does not agree with the findings of Pascoe and Shazili (1985), who concluded that irreversible toxic effects can occur in the absence of toxicant bioaccumulation. Therefore, this model is appropriate only when the toxic effect results from tissue accumulation.

In calibrating this model and applying it to experimental data, a number of limitations became evident. First, the one-compartment first-order kinetics equation is not appropriate for all organisms and toxicants. In the *Vibrio fischeri* model calibration, for example, negative depuration rates were obtained for the 80, 90 and 100% sensitivity levels. In these cases, an alternative equation should be used for modeling toxic effects due to time-variant exposures.

Another limitation of the model is that it should be calibrated using solutions within the range of contaminant concentrations being examined. The lowest zinc concentration in the *V. fischeri* model calibration was 1.0 mg/l. From all of the samples collected at the Forth Worth field sites, only one contained zinc in excess of this lowest calibration concentration (1.27 mg/L Zn at Cra during the May 24 storm). As a result, model predictions of light inhibition were made by extrapolating the laboratory results to lower zinc concentrations that were observed in the field. This might have caused the model to overpredict light inhibition at low zinc concentrations. As mentioned earlier, negative light inhibition was measured in *V. fischeri* that were exposed to low zinc concentrations during the continuous exposure test. These light stimulation effects were not incorporated into the model, and this proved to be an important omission because stimulation was observed in many of the samples collected from the Fort Worth field sites.

Storm Sewer Drainage Model. Application of an available model is often a compromise between detail and availability of model input and the expected use of model output. As this project evolved from a focus on in-stream analysis of time-scale toxicity to a focus on in-pipe and near-outfall assessment, a need developed to model outfall hydrology to assist in both interpretation of toxicity during storm events, and prediction of toxicity as affected by storm sewer system characteristics. The focus on the KLSS system required an analysis of the sewer "tributary" system to identify possible sources of contaminants. Further, modeling suggested itself as a means to supplement toxicity testing with information on sewer dynamics that would assist in developing contaminant source and frequency and duration of exposure information.

The most widely used model for this type of analysis is the Stormwater Management Model (SWMM). Unfortunately, SWMM is a complex model that required input data detail that was not readily available. A second model, the Illinois Urban Drainage Area Simulator (ILLUDAS) was developed locally, had minimal input data requirements, and was supported locally. ILLUDRAIN (Ver 2.10) was applied to the KLSS system.

Information on storm sewers was obtained from the Champaign Department of Public Works (Figure B-48), and a general system configuration was identified that accurately represented actual system layout, which had the sewer network divided into branches and then subdivided into reaches with known contributing areas. Two storms were selected for modeling. A two-hour storm that occurred on June 23, 1994, and a four-hour storm on September 26, 1994, provided representative medium intensity storms of different duration. Model sensitivity was tested for different antecedent moisture condition (AMC) for these storms. The effect of rainfall amount was investigated using three storms, the one-year, two-hour rainfall, the June 23, 1994, storm and a storm of low intensity.

The results of this modeling are provided in Figures B-49 and B-50. Figure B-49 is the estimated hydrograph for a two-hour storm during which antecedent moisture conditions produced no change in hydrograph prediction. Figure B-50 provides model results for storms of different intensities. The model predicts a maximum discharge of 50 ft^3/sec with a maximum discharge occurring at approximately 45 minutes. Field measurements indicated a similar storm produced a maximum discharge of 40 ft^3/sec, and time to peak was generally observed within an hour of rainfall.

The application of ILLUDRAIN found that the model is sensitive to the percent grassed area in a watershed. Further, the model provides an option for identifying local surface hydrographs that assist in identifying sources of contaminants that vary through a single storm event.

Conclusions and Applications

In assessing the impact of wet weather events, time-scale considerations are the basis for selecting appropriate toxicity assessment procedures. If an acute toxic response is the indicator of impact, then short-term exposures (intra-event time scale) are most appropriate. In an intra-event analysis, concentration transients are sometimes very large (orders of magnitude), and the responses assessed need to match the time scales of exposure that occur during the storm event.

Figure B-48. Kaufman Lake Storm Sewer Watershed with Major Sewers Indicated

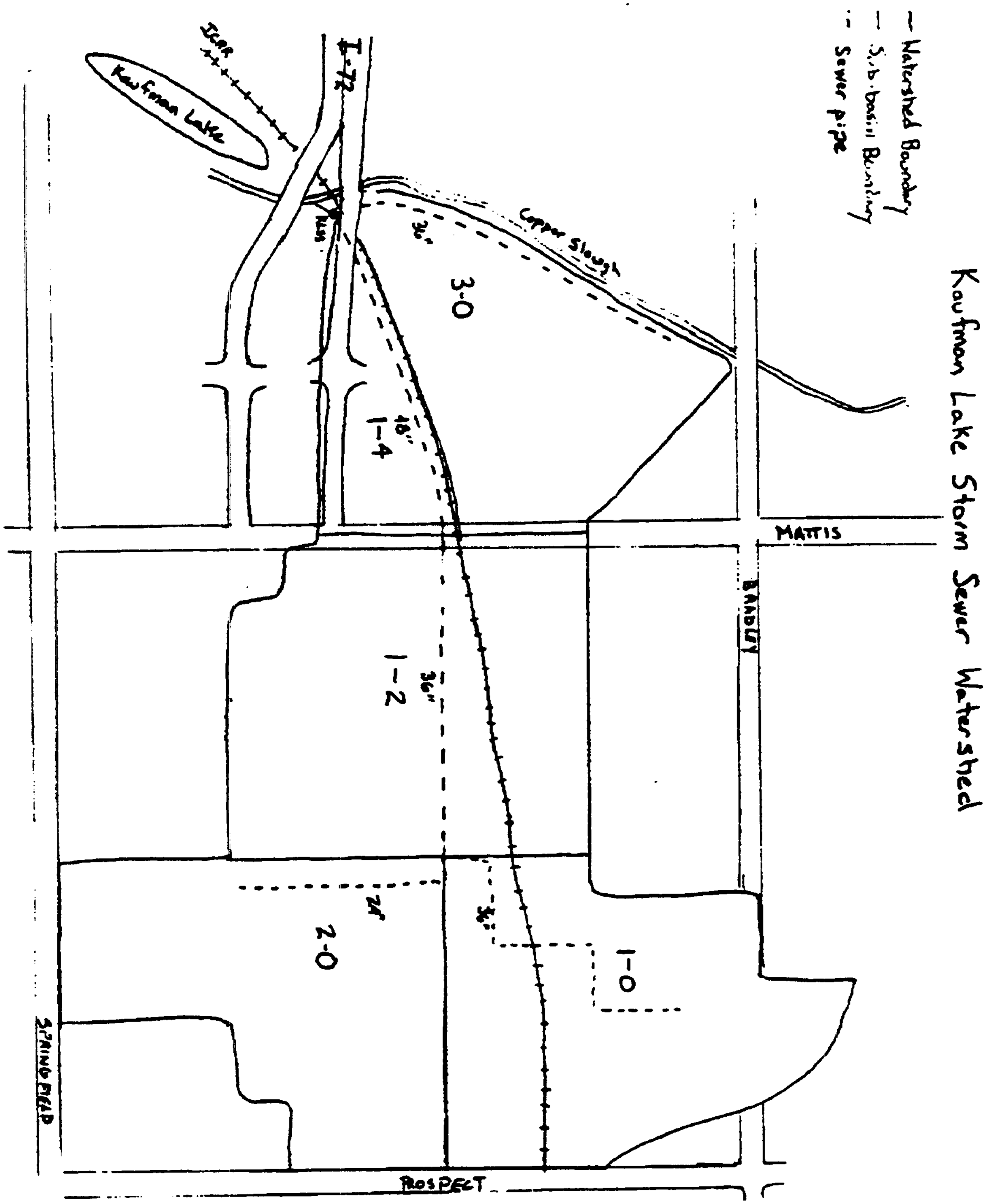


Figure B-49. Estimated Hydrograph for a Two-Hour Storm

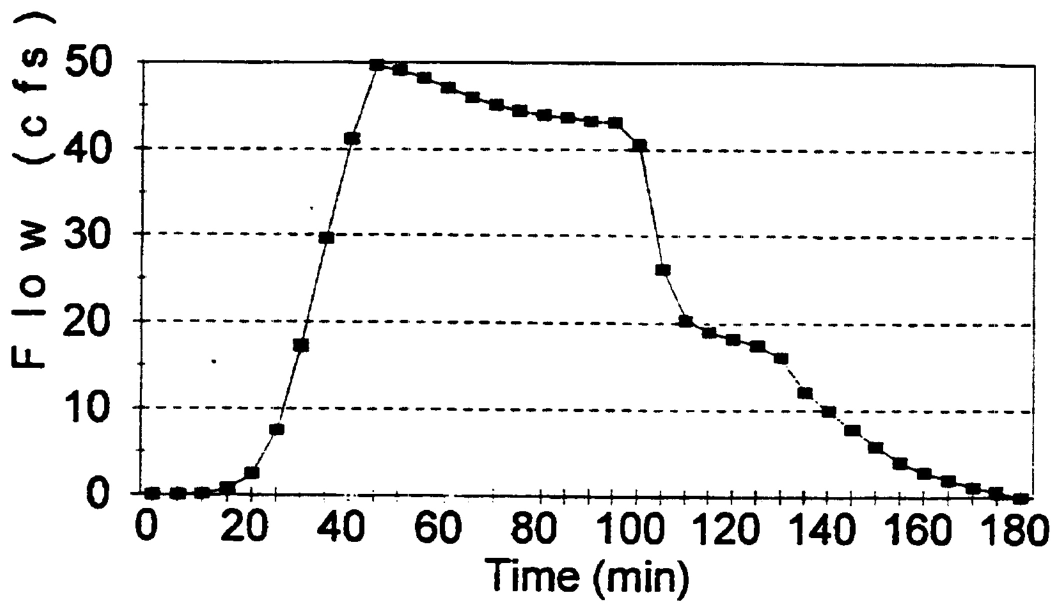
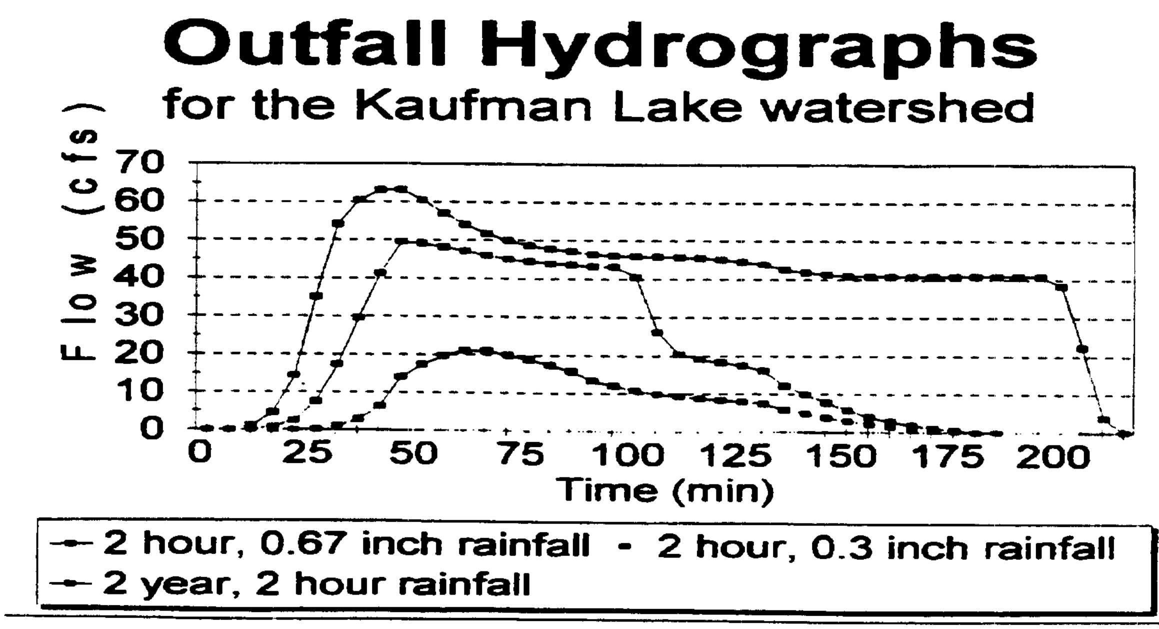


Figure B-50. Predicted Hydrographs for the KLSS Outlet for Different Intensity Storms



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Furthermore, since different test systems show different time scales of responses to toxicants, one test cannot be relied upon to detect toxicity in all wet-weather events. Consequently an optimized test battery is needed to accurately assess toxicity (e.g., minimize incidences of both false negatives and false positives in toxicity test results) associated with events of different duration. The need to use a test battery for time-scale toxicity testing is consistent with the consensus view of regulators involved in controlling point source discharges (US EPA, 1991; Environment Agency, 1996). The optimal test battery for assessing intra-event (and event or long-term toxicity) should be selected according to specific criteria and must be cost effective and accurate. Test batteries should avoid unnecessary redundancy (that is, tests that yield similar responses); if two or more tests consistently show the same response to samples and using both provides no additional information, there is clearly redundancy and using only one test improves cost effectiveness.

The identification of appropriate test batteries for each time-scale division has been a key element of the project and has been supported by the results presented in this section, which support the test systems selection procedure described in Chapter 4.0.

For intra-event analysis, test systems must be responsive to exposure durations in the order of minutes to as long as a few hours. Sequential sampling during an event assists in both identifying toxicity transients, which have been shown by laboratory testing to produce delayed response, and provides a basis for accurate ETU determination. Research conducted in this project has identified test methods, such the acute Microtox procedure and the Inhibitory Quotient (IQ) test using *C. dubia* and *H. azteca*, as being appropriate for intra-event analysis, as well as modified time-scale specific versions of WET tests using *C. dubia* and *H. azteca*, which simulate the pulsed exposure conditions found in storm events. These test systems provide a more appropriate means of assessing the effects of time-scale toxicity and account for both delayed effects and organism recovery.

The laboratory-based time-scale toxicity research also indicated:

- The need for modification of the existing IQ test method to ensure that high levels of suspended material in stormwater samples do not markedly reduce enzyme activity because organisms are ingesting these particulates rather than the test substrate; and

- The need to carefully assess the results of Microtox tests in view of the stimulation of light output seen in many receiving water samples before and after storm events due to the hormesis effect of low contaminant concentrations in the samples.

This battery of tests has been evaluated in the monitoring programs that assess intra-event toxicity during wet-weather events at different locations. This regional evaluation has demonstrated the applicability of WET derived time-scale toxicity tests and the clear need to implement specific time-scale toxicity testing for wet-weather discharge impact assessment.

The research has also identified a series of modeling and testing procedures approaches that can to predict toxicity, assist in sampling design, and identify the causative agent(s) and or sources of toxicity once high or moderate toxicity has been measured using the basic screening tests.

APPENDIX C

INTEGRATING TIME-SCALE ISSUES IN ECOSYSTEM MANAGEMENT

Ecosystem-Based Management

Objective #4 of the research was to "Develop an ecosystem-based management context for wet weather discharges, which integrates the need for both regulatory criteria and the protection of ecosystem health." An ecosystem context for time-scale toxicity was presented in Herricks, Milne, and Johnson (1994). Further conceptual developments have been made to develop a paradigm for integration of time-scale issues in ecosystem-based management.

Paradigm Description

The paradigm for integrated ecosystem management is based on scalar definition of critical ecosystem properties and processes that include both spatial and temporal issues in the disturbance/distance paradigm. This paradigm is the basis for development of an assessment template that defines critical ecosystem issues that must be addressed to: 1) assess success or failure of wet weather management programs without bias; 2) define critical measures of structure and/or function affected by wet weather flows to support management; 3) support modeling that follows a risk-based analysis for ecosystem management strategies; and 4) effectively integrates testing, assessment, and modeling to illuminate likely outcomes of a management strategy.

The disturbance/distance paradigm is based on the recognition that from the center point of a disturbance, there will be zones of decreasing effect with distance (Figure C-1). Because disturbance differentially affects ecosystem properties and processes in each of these zones, the measures necessary to assess effect also change with distance and reflect changes in complexity, disturbance dominance, effect type, etc. In addition to a disturbance control in this template, there is also an influence from undisturbed "natural" areas operating in a direction opposite to the disturbance, which leads to restoration. Since ecosystem properties and processes have a natural tendency to some equilibrium state, driven by homeostatic mechanisms, the combined influence of disturbance and restoration produce the ecosystem state or condition observed in an assessment. The disturbance/distance paradigm applies both damage functions and recovery functions in the assessment of sustainability in any zone.

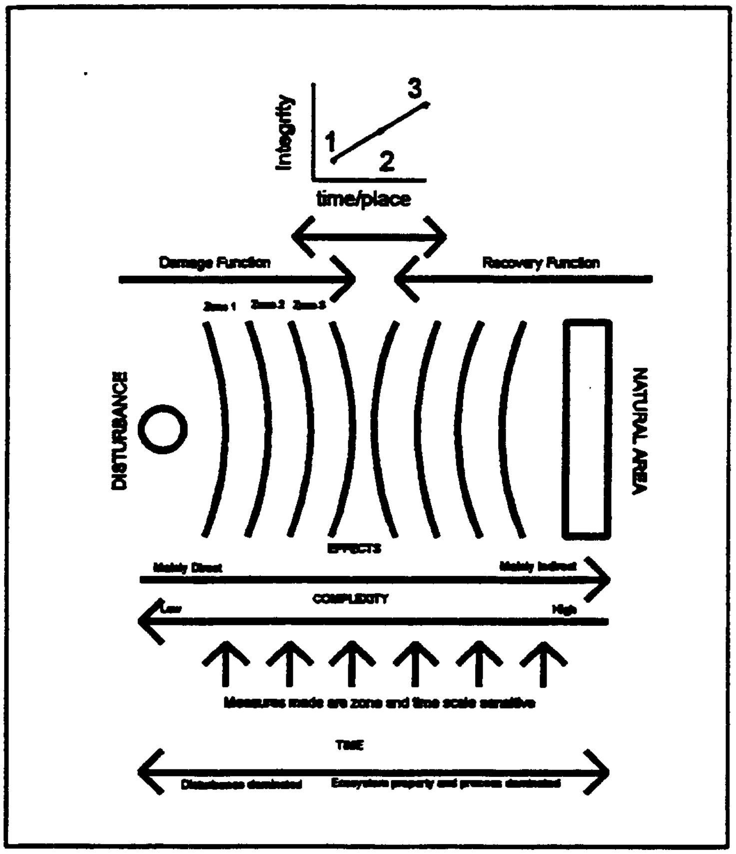

Figure C-1. Illustration of Distance Disturbance Paradigm, Coupling Spatial and Temporal Dimensions for Ecosystem Management

The mechanisms that sustain state or condition can be related to critical scalar constraints (spatial or temporal dimensions of ecosystem properties and processes) that are largely defined by internal ecosystem processes rather than some arbitrary divisions driven by external factors (location, climate, etc.). The disturbance/distance paradigm, based on these ecosystem processes and properties, also considers a temporal scale for analysis that is appropriate for each zone. A disturbance/distance temporal scale is established based on properties or processes dominant in each zone and a time scale of effect that is defined by the level of disturbance/concentration influencing each zone. For example, if the zone of analysis is close to a high level of disturbance (e.g., in-pipe or near pipe areas), the time scale appropriate for an effect analysis will be short, e.g., an acute response. As the distance from the disturbance increases, the time required to produce a given effect also increases because exposure concentrations are reduced, moving the response to a chronic response time frame. The disturbance/distance paradigm recognizes that, with distance, an effect analysis shifts from an emphasis on simple (direct, and short-term cause and effect) relationships to more complex (largely indirect, and long-term) mechanisms that produce change in an ecosystem. An alternative view of the disturbance/distance paradigm is produced when the analysis begins with a natural location, unaffected by the identified disturbance. In this "recovery-based" system, the distance from the natural location is also used to describe "relative influence" and constrain recovery mechanisms. In general, the distance and time scales appropriate to analysis are inverted in this recovery-based example; that is, restoration occurs rapidly in areas at some distance from the point of disturbance and require more time closer to the point of disturbance. The critical issue is still that ecosystems must be assessed recognizing the influence of both space and time on an observed state and condition.

Applying this disturbance/distance template to ecosystem management establishes critical spatial and temporal scale factors for ecosystem analysis. Furthermore, the template operates independently of regional differences and provides a basis for allocation of effort and expectations for success in management programs. To illustrate this point, consider a template based on an urban center as the focus for establishing a distance-based analysis. In the agricultural Midwest, general habitat heterogeniety can be considered low. Here, the spatial scales of natural ecotones are large and the basic scale of application from a single site might be large. Furthermore, the large scales associated with similar conditions suggests that few reference sites would be needed to adequately address ecosystem differences (note: thus this relatively large scale leads to the selection and application of fewer different assessment tools and approaches). If the Pacific Northwest is the focus for analysis, the spatial scale for analysis is much different because the landscape is highly variable. The spatial scales of natural ecotones in this setting are small so applicability of measurements made at a single site may be limited. The differences associated with selection of even small spatial scales in an assessment activity would require more reference sites. The result of the application of the distance-based template will be the redefinition of assessment and management needs that better reflect the reality of both natural conditions and the influence of human activity in each setting (or region).

The proposed disturbance/distance paradigm, and the assessment template, finds support in recent research agenda. Naiman et al. (1995) provide a comprehensive summary of the Freshwater Imperative (FWI), an effort to "identify research opportunities and frontiers in inland water ecology." They recognize that a clear need exists for an understanding of the causes of disturbance and degradation and how systems respond to, and recover from, disturbance and degradation. The FWI research agenda focuses on evaluation of responses to disturbance, pathways of recovery, measurement of progress to new equilibria, and identification of conditions under which systems shift to new equilibrium states. The Watershed Protection Approach (WPA) proposed by US EPA (1993) emphasizes environmental indicators, which are measurable features that singly or in combination provide useful evidence of ecosystem quality or reliable evidence of trends in. The environmental ndicator effort is particularly valuable, because it addresses the critical area of measurement utility and provides guidance for a range of indicators that can be used to both judge quality and assess the stage of restoration. The disturbance/distance paradigm can be the basis for focusing research to key questions in time-scale toxicity and wet weather discharge impact analysis.

Space and Time Integration

With the recognition of the need for integrated ecosystem management and the need for conducting ecological assessments at multiple ecological scales, particularly in regional assessments, there is a critical need for more exact definition of "scale" in ecosystems. In fact, a major element of the currently practiced ecosystem health paradigm is the argument that the fundamental unit in assessing ecosystems is an "area," such as a habitat, ecoregion, landscape, or a biome. In this health assessment, it is necessary to define an area and provide a corresponding identification of critical properties and processes. Examples of inexact coupling of spatial and temporal scales in the selection of critical ecosystem measures illustrates that an "area" is not fixed by size, rather it changes with time. Here, it may be valuable to consider the Schumm and Lichty time-scale synthesis (discussed in the following paragraphs), which suggests, as viewed from different time perspectives, how cause and effect relationships shift from internal to external. For example, internal factors, such as feedback (homeostatic) processes, operate in a time scale defined by equilibrium maintenance. External factors can operate over longer time scales as dependence and independence relationships change. It is the integration of temporal scale issues in analysis that allows productive assessment and successful management (Herricks et al., 1996).

To begin the process that selects measures of ecosystem state or condition, we need to define the boundaries of "areas" both in space and time. In analyzing these dimensional issues, we can advance ecosystem analysis by using concepts borrowed from geomorphology. As illustrated in Table C-1, scale issues are well-defined topographically in drainage basins/watersheds. For each scale, a system of measurement is available, and relationships between scales and among their spatial dimensions are defined. Geomorphologists have also developed an effective method of working with temporal scales. Three decades ago, Schumm and Lichty (1965) proposed a conceptual framework for geomorphologic time that classifies time span and the changing relationships among system variables that occur when temporal scales are changed. The three time spans they defined (cyclic, graded, and steady) do not have an absolute value, but differ in duration. Cyclic time is long, related to an erosion cycle of uplift and erosion to some level—this time span may be related to evolutionary time scales. Graded time is a short span of cyclic time that might be associated with a graded, or equilibrium, river profile—related to stable equilibria in ecosystems and defined by multiple generations of long- lived species. Steady time is a very short time period, applicable to processes that occur along a river reach—related to change within the life cycle of a long-lived species. With the definition of these temporal scales, Schumm and Lichty also provided a system that assists in relating variables in each time span by considering how independence/ dependence relationships change with the perspective of time scale. Table C-1 illustrates the changing status of variables as different time scales are considered. It is this insight into the changing independence/dependence relationships with time-scale perspective that directs an ecosystem assessment to consider the appropriate time scales of properties and processes, then define the independent variable(s) that are to be used in a cause-and-effect analysis.

Table C-1. Relationship of River Variables as Established by Time-Scale Perspective (After Schumm and Lichty, 1965)

		Status of variables during designated time spans		
	River Variables	Cyclic/Geologic	Graded/Modern	Steady/Present
1	Time	Independent	Not relevant	Not relevant
2	Geology	Independent	Independent	Independent
3	Climate	Independent	Independent	Independent
4	Vegetation	Dependent	Independent	Independent
5	Relief	Dependent	Independent	Independent
6	Palaeohydrology (long-term discharge of water and sediment)	Dependent	Independent	Independent
7	Valley dimensions (width, depth, slope)	Dependent	Independent	Independent
8	Mean discharge of water and sediment	Indeterminate	Independent	Independent
9	Channel morphology (width, depth, slope, shape, pattern)	Indeterminate	Dependent	Independent
10	Observed discharge of water and sediment	Indeterminate	Indeterminate	Dependent
11	Observed flow characteristics (depth, velocity, turbulence, etc.)	Indeterminate	Indeterminate	Dependent

Following the Schumm and Lichty (1965) approach, we propose that procedures be developed for integrated analysis that consider spatial and temporal scales for any "area" definition, e.g., in watersheds. At large spatial and temporal scales, the emphasis can be on multiple stressors, while time is related to ecological processes, such as evolution and succession. At smaller spatial scales, the emphasis can be on single stressors with a focus on concentration and duration of exposure where individual and population response is assessed. Furthermore, spatial and temporal scales define externalities, which are of importance in defining independence and dependence, and most importantly, cause and effect. As scales of analysis are reduced, more environmental and ecological variables can be considered independent, leading to a focus on individual, population, or community indicators that relate cause and effect, and direct management efforts to specific actions (Herricks et al., 1996; Wallin and Schaeffer, 1979).

Frissell et al. (1986) proposed a habitat-centered view of stream systems (Table C-2). Their view is based upon a hierarchical organization of habitat types. In this hierarchical organization, subsystems (stream segment, reach, pool/riffle, and microhabitat) develop and persist within a specified spatio-temporal scale. In this "systems" view, high frequency, low-magnitude geomorphic events predominate in the subsystems, while the system as a whole is subject to low frequency, high magnitude events. A critical issue in the hierarchy is that the setting within which components, processes, and dynamics are defined is provided by the next higher level in the hierarchy. These "nested" relationships in the hierarchy provide an example of the integration of Schumm and Lichty's (1965) time-scale perspective, illustrating the change in dependence relationships at different levels of the hierarchy. A recognition of this change in controlling variables with time-scale perspective is particularly important in ecological assessments.

The organizational framework provided by topographic, temporal, and system hierarchies provides a foundation for the examination of environmental system dynamics critical in defining and dealing with ecological assessment issues in wet weather discharge analysis and management practices for environmental protection. For example, a critical metric near the disturbance might be a rapid measure of direct toxicity while at a distance it may be a measure of recovery or succession. This is the foundation of a distance/disturbance-based paradigm that will select appropriate time-scale measures at defined distances where operational differences of processes are evident or where properties are consistent.

Table C-2. Expected Spatial and Temporal Scales, Events, Processes, and Water Quality Issues (Modified from Frissell et al., 1986)

Level in Watershed Hierarchy/Scale	Spatial scale (km)	Time Span	Expected Duration (years)	Landscape Change Characteristics	Process Characteristics	Water Quality Issues
Stream system/Basin	$10^3 - 10^4$	Cyclic/ Geologic	$10^6 - 10^5$	Tectonic uplift, subsidence, sea level changes, glaciation	Planation; denudation; drainage network development	Source materials established in watershed; weathering products dependent on parent materials and exposure conditions
Segment system/Network	$10^2 - 10^3$	Cyclic/ Geologic	$10^4 - 10^3$	Minor glaciation, earthquakes, very large landslides, alluvial or colluvial valley infilling; river meander pattern development	Migration of tributary junctions and bedrock nickpoints, channel downcutting, extension of first-order channels	Periodic exposure of unweathered materials may lead to water quality differences in basin; expectation of mid- to late-stage weathering products; more complete channel network increases potential for landscape change to affect water quality
Reach system/Channel Reach	$10^1 - 10^2$	Graded/ Modern	$10^1 - 10^2$	Debris torrents; landslides; channel shifts; river meander cutoff; channelization, diversion or damming by man	Aggradation/degradation associated with sediment storage structures; bank erosion; riparian vegetation succession	Loading emphasis; focus on input, output, and residence time of weathering products and contaminants; adjustment of channel form to sediment loading and corresponding storage of contaminated materials; exposure times changing from chronic to acute
Pool/Riffle system/Channel Cross-section	10^0	Steady/ Present	$10^1 - 10^0$	Sediment accumulation/washout; small bank failures; floodflow scour/deposition; thalweg shift; alternate bar change	Small-scale lateral or elevational changes in bedforms	Shift to concentration emphasis; presence of "hot spots" of contamination; water column/dissolved contaminants of greater importance; emphasis on acute exposure levels
Microhabitat system	10^{-1}	Steady/ Present	$10^0 - 10^{-1}$	Annual flow/sediment/organic matter transport, substrate scour; seasonal macrophyte/periphyton growth and scour	Seasonal depth, velocity changes; sediment accumulation; biological processes	Concentration and duration variability high; mixing zone issues important; emphasis on less than acute exposures that emphasize return frequency and timing of water quality alteration

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Issues associated with time scales can also be specifically addressed in the paradigm. For example, the episodic nature of wet weather flows can take advantage of the paradigm to more effectively perform a time-scale effect analysis in any more general system assessment. This requires that traditional toxicity testing procedures, which assume constant flow, are deemed inappropriate for the assessment of episodic exposures produced by, in particular, stormwater/wet weather discharges. In storm events, concentrations can vary over several orders of magnitude in very little time (seconds to minutes). In addition, the paradigm accommodates the situation where cumulative effects that include both the frequency of exposure and the accumulation/storage of contaminants leads to system degradation.

The issue of time in water quality can be addressed by a temporal scale segregation. Following Schumm and Lichty (1965), it is possible to establish three time perspectives. The first is short-term, a non-steady-state time increment. This time increment, at its shortest, includes episodic exposure and, at its longest, is based upon organism life span criteria that are used in an effect assessment. An acute, non-recurring fluctuation in water quality produced by a contaminant spill, or a less toxic, but more frequent episodic exposure will be typical of this time dimension. A second time perspective is a quasi-steady state. This time scale finds water quality conditions that are dominated by either a constant discharge or a constant release from stored components. The exposure conditions can vary as evidenced by decreasing concentrations with flow. The critical exposure measure is chronic toxicity or long-term population maintenance. The third time perspective is long, integrating water quality conditions through time that are associated with landscape change. Over this time frame, gradual change or a punctuated alteration that produces a new "stable" state, will find alteration in both system properties and the fundamental processes that control water quality.

In summary, the time-scale segregation adopted in the distance/disturbance paradigm is appropriate to the range of causes and a variety of sources. A short time scale will reflect the short-term variability typical of wet weather events. An intermediate time scale will accommodate the constancy of input, typical of baseline conditions. A long time scale will reflect cumulative effects and trends and is appropriate for determination of watershed/landuse influence on channel water quality, in particular the accumulation of contaminants in the receiving system.

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ABSTRACT

The results of a national assessment of research needs in managing urban wet weather flow are divided into three interrelated categories: combined sewer overflows, sanitary sewer overflows, and urban wet weather flow discharges. The initial compilation of 154 wet weather flow research projects was reduced to 69 higher priority projects for which detailed literature reviews were compiled. From this group, 26 topics were identified as high priority for research. The results of this assessment were organized into ten categories: (1) sources and monitoring; (2) receiving water impacts; (3) other impacts; (4) management; (5) models and decision support systems; (6) watershed management linkages; (7) regulatory policies and financial aspects; (8) source controls; (9) collection system controls; and (10) storage and treatment systems. Addressing the identified research would require an estimated $20 million to $40 million per year.

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A RESEARCH NEEDS SURVEY FOR URBAN AREAS

PROJECT 96-IRM-1

1998

by

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BENEFITS

- Reviews previous research needs assessments and offers a vision of gains expected from additional research;

- Examines closely such major topics as sources and monitoring, receiving water and other impacts, management, models and decision support systems, watershed management linkages, regulatory policies and financial aspects, source controls, collection system controls, and storage and treatment systems;

- Assesses 69 topics in the wet weather flow research. This assessment includes a literature review and statement of the problem, description of the research needs on the topic, and key references;

- Reviews innovative urban wet weather water management from an international perspective; and

- Prioritizes topics for additional, targeted research efforts according to cost effectiveness and provides cost estimates for identified research needs.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	III
BENEFITS	VII
LIST OF TABLES	XIX
LIST OF FIGURES	XXI
EXECUTIVE SUMMARY	ES-1

1.0 INTRODUCTION

1.1 The Problem and Opportunities	1-1
1.2 Intended Audiences for this Research Needs Assessment	1-1
1.3 Vision for the Benefits of Urban WWF Research	1-2
1.4 Preview of the Remainder of the Report	1-3

2.0 PREVIOUS WET WEATHER RESEARCH NEEDS ASSESSMENTS

2.1 Literature Review	2-1
2.2 Wet Weather Flow Research	2-1
2.3 Previous Research Needs Assessments	2-2
2.3.1 1986 Compilation by Torno	2-2
2.3.2 1986 Research Needs Assessment by Heaney	2-4
2.3.3 1990 WPCF Research Needs Assessment	2-6
2.3.4 US EPA Research Needs Assessment	2-6
2.3.5 1996 WERF/Bay Area Stormwater Management Agencies Wet Weather Research Needs Assessment	2-10
2.3.6 October 1996 WERF WWF Research Needs Workshop, Dallas, Texas	2-11
2.3.7 Recommendations from the 1997 Malmö Conference	2-12
2.3.8 Compilation of Research Needs Efforts	2-16
2.4 Methods for Assessing Research Needs	2-21
2.5 Purposes of Urban Stormwater Research Program	2-21
2.6 References	2-23

R0025686

TABLE OF CONTENTS, CONT.

3.0 SOURCE CHARACTERIZATION

3.1 The Problem 3-1
3.1.1 References 3-6
3.2 Characterization of Pollutants Associated with Urban Land Use 3-8
3.2.1 Research Needs 3-8
3.2.2 References 3-9
3.3 Physical Transport and Wash-Off Processes 3-10
3.3.1 Research Needs 3-10
3.3.2 References 3-11
3.4 Monitoring 3-11
3.4.1 Research Needs 3-12
3.4.2 References 3-12

4.0 RECEIVING WATER IMPACTS

4.1 General Topics 4-1
4.1.1 References 4-6
4.1.2 Rivers, Lakes, Estuaries, and Wetlands 4-9
4.1.2.1 Research Needs 4-9
4.1.2.2 References 4-10
4.1.3 Nutrient, Metals, and Toxicant Cycling 4-10
4.1.3.1 Research Needs 4-11
4.1.3.2 References 4-11
4.1.4 Biomonitoring and Bioassessments 4-12
4.1.4.1 Research Needs 4-13
4.1.4.2 References 4-13
4.1.5 Benthic and Sediment Impacts 4-14
4.1.5.1 Research Needs 4-15
4.1.5.2 References 4-15
4.1.6 Land Use, Urbanization, and Geomorphology 4-15
4.1.6.1 Research Needs 4-16
4.1.6.2 References 4-16
4.2 Groundwater and Vadose Zone 4-17

TABLE OF CONTENTS, CONT.

4.2.1 Stormwater-Groundwater-Vadose Zone Impacts 4-17
4.2.1.1 Research Needs 4-18
4.2.1.2 References 4-18
4.3 Human Health 4-19
4.3.1 Human Health Risks and Ecosystem Impact Trade-offs 4-19
4.3.1.1 Research Needs 4-20
4.3.1.2 References 4-20

5.0 MANAGEMENT

5.1 Organizational Structure 5-1
5.1.1 Reference 5-1
5.2 Models and Decision Support Systems 5-2
5.2.1 References 5-10
5.2.2 Enhancements in Existing Models 5-16
5.2.2.1 Graphical User Interface/Object Oriented Programming 5-16
5.2.2.1.1 Research Needs 5-16
5.2.2.1.2 References 5-17
5.2.2.2 Improvements in the Analysis of Rainfall Input Data 5-17
5.2.2.2.1 Research Needs 5-18
5.2.2.2.2 References 5-18
5.2.2.3 Improved Parameter Estimation Techniques 5-19
5.2.2.3.1 Research Needs 5-20
5.2.2.3.2 References 5-20
5.2.2.4 Data Centered Approaches to Enhancing Stormwater Modeling 5-21
5.2.2.4.1 Real-Time Control 5-21
5.2.2.4.1.1 Research Needs 5-22
5.2.2.4.1.2 References 5-22
5.2.2.4.2 Stochastic Simulation 5-23
5.2.2.4.2.1 Research Needs 5-23
5.2.2.4.2.2 References 5-23
5.2.2.4.3 Neural Network 5-24
5.2.2.4.3.1 Research Needs 5-25
5.2.2.4.3.2 References 5-25

TABLE OF CONTENTS, CONT.

5.2.2.4.4 Calibration of Transport Models Using Improved Databases 5-26
5.2.2.4.4.1 Research Needs 5-26
5.2.2.4.4.2 References 5-27
5.2.2.5 Linking Surface and Subsurface Phenonmena 5-27
5.2.2.5.1 Research Needs 5-28
5.2.2.5.2 References 5-28
5.2.2.6 Linking with Atmospheric Models 5-29
5.2.2.6.1 Research Needs 5-29
5.2.2.6.2 References 5-30
5.2.2.7 Solids in Sewers/Sewer System Modeling 5-30
5.2.2.7.1 Research Needs 5-31
5.2.2.7.2 References 5-31
5.2.3 Integrated Decision Support Systems 5-32
5.2.3.1 Research Needs 5-33
5.2.3.2 References 5-33
5.2.3.3 Integrate GIS to Refine Spatial Analysis Capabilities 5-34
5.2.3.3.1 Research Needs 5-34
5.2.3.3.2 References 5-35
5.2.3.4 Interface Simulation and Optimization Models 5-36
5.2.3.4.1 Research Needs 5-36
5.2.3.4.2 References 5-36
5.2.3.5 Integrated DSS for Overall Watershed 5-37
5.2.3.5.1 Watershed Models 5-37
5.2.3.5.1.1 Research Needs 5-38
5.2.3.5.1.2 References 5-38
5.2.3.5.2 Ecosystem Models 5-39
5.2.3.5.2.1 Research Needs 5-39
5.2.3.5.2.2 References 5-40
5.2.3.6 Risk Management Methodologies 5-40
5.2.3.6.1 Research Needs 5-41
5.2.3.6.2 References 5-41
5.3 Watershed Management Linkages 5-42
5.3.1 References 5-44
5.3.2 Watershed Assessment Methodology 5-47
5.3.2.1 Research Needs 5-47
5.3.2.2 References 5-47
5.3.3 Long-Term Watershed Case Studies 5-48

TABLE OF CONTENTS, CONT.

5.3.3.1 Research Needs 5-49
5.3.3.2 References 5-49
5.3.4 Urban Research Catchment Network 5-50
5.3.4.1 Research Needs 5-50
5.3.4.2 References 5-50
5.3.5 Watershed-Based Water Quality Standards 5-51
5.3.5.1 Research Needs 5-51
5.3.5.2 References 5-52

6.0 REGULATORY POLICIES AND FINANCIAL ASPECTS

6.1 Regulations and Permits 6-1
6.1.1 References 6-5
6.1.2 Preparing Effective and Implementable NPS Watershed Goals 6-7
6.1.2.1 Research Needs 6-8
6.1.2.2 References 6-8
6.1.3 Determining Areas Where Regulatory Flexibility Can Achieve Watershed Goals 6-8
6.1.3.1 Research Needs 6-9
6.1.3.2 References 6-9
6.2 Reuse and Water Resources 6-10
6.2.1 References 6-14
6.3 Financing and Cost Analysis 6-17
6.3.1 References 6-18
6.3.2 Methods of Financing 6-18
6.3.2.1 Research Needs 6-19
6.3.2.2 References 6-19
6.3.3 Methods of Cost Allocation 6-20
6.3.3.1 Research Needs 6-21
6.3.3.2 References 6-21
6.3.4 Development of Cost/Performance Data for Controls 6-22
6.3.4.1 Research Needs 6-22
6.3.4.2 References 6-23
6.4 Benefits of Urban Wet Weather Flow Management 6-23
6.4.1 References 6-27

TABLE OF CONTENTS, CONT.

6.4.2 Contingent Valuation 6-31
6.4.2.1 Research Needs 6-32
6.4.2.2 References 6-32
6.4.3 CSO Measures of Success 6-33
6.4.3.1 Research Needs 6-34
6.4.3.2 References 6-34
6.5 Education and Outreach 6-35
6.5.1 References 6-36
6.5.2 Public Involvement, Participation Techniques 6-37
6.5.2.1 Research Needs 6-38
6.5.2.2 References 6-38
6.5.3 Coordination of Wet Weather Flow Research Across Agencies 6-39
6.5.3.1 Research Needs 6-39
6.5.3.2 References 6-39

7.0 CONTROL TECHNOLOGIES

7.1 On-Site Control 7-1
7.1.1 References 7-6
7.1.2 Swales 7-8
7.1.2.1 Research Needs 7-8
7.1.2.2 References 7-9
7.1.3 Modifying Urban Surfaces to Reduce Hydraulic and Pollutant Loads 7-9
7.1.3.1 Research Needs 7-10
7.1.3.2 References 7-10
7.1.4 Reduce Inflow and Infiltration in House Service Laterals 7-11
7.1.4.1 Research Needs 7-12
7.1.4.2 References 7-12
7.1.5 Urban Drainage Design Improvements for Micro-Storms 7-13
7.1.5.1 Research Needs 7-13
7.1.5.2 References 7-14
7.1.6 Stormwater Reuse 7-14
7.1.6.1 Research Needs 7-15
7.1.6.2 References 7-15
7.1.7 Storm Inlet Devices 7-16
7.1.7.1 Research Needs 7-17

TABLE OF CONTENTS, CONT.

7.1.7.2 References 7-17
7.1.8 Industrial Runoff Control 7-17
7.1.8.1 Research Needs 7-18
7.1.8.2 References 7-19
7.1.9 Reuse of Urban Runoff as Cooling Water 7-19
7.1.9.1 Research Needs 7-19
7.1.9.2 References 7-20
7.1.10 Roadway and Airport Deicing 7-20
7.1.10.1 Research Needs 7-21
7.1.10.2 References 7-21
7.2 Collection Systems 7-21
7.2.1 References 7-25
7.2.2 Instrumentation and Monitoring to Evaluate Sewer Hydraulics 7-28
7.2.2.1 Research Needs 7-29
7.2.2.2 References 7-29
7.2.3 Laboratory and Field Studies of Deposition and Scour in Sewers 7-30
7.2.3.1 Research Needs 7-31
7.2.3.2 References 7-31
7.2.4 Use of Simulation Models in Storm Sewer Design 7-31
7.2.4.1 Research Needs 7-32
7.2.4.2 References 7-32
7.2.5 Cost-Effective Ways to Rehabilitate and Replace Old Sewers 7-33
7.2.5.1 Research Needs 7-34
7.2.5.2 References 7-34
7.2.6 Improved Inflow and Infiltration Control in Sanitary and Storm Sewers 7-35
7.2.6.1 Research Needs 7-35
7.2.6.2 References 7-36
7.2.7 Sewer Maintenance Effectiveness 7-36
7.2.7.1 Research Needs 7-37
7.2.7.2 References 7-37
7.2.8 Sewer and Tank Sediment Flushing 7-38
7.2.8.1 Research Needs 7-38
7.2.8.2 References 7-39
7.2.9 Innovative Design of Sanitary and Storm Sewers 7-39

TABLE OF CONTENTS, CONT.

7.2.9.1 Research Needs 7-40
7.2.9.2 Reference 7-40
7.3 Storage and Treatment 7-40
7.3.1 References 7-44
7.3.2 Sanitary Sewer Overflows 7-47
7.3.2.1 Research Needs 7-47
7.3.2.2 References 7-48
7.3.3 High Rate Operation of Wastewater Treatment Plants 7-48
7.3.3.1 Research Needs 7-49
7.3.3.2 References 7-50
7.3.4 High Rate CSO Treatment—Vortex Separators 7-50
7.3.4.1 Research Needs 7-51
7.3.4.2 References 7-51
7.3.5 High Rate CSO Treatment—Disinfection 7-52
7.3.5.1 Research Needs 7-52
7.3.5.2 References 7-53
7.3.6 Advanced High Rate Treatment—Magnetic and Chemical Additives 7-53
7.3.6.1 Research Needs 7-54
7.3.6.2 References 7-54
7.3.7 Control of Solids 7-55
7.3.7.1 Research Needs 7-56
7.3.7.2 References 7-56
7.3.8 Characterization and Treatment of Toxics and Metals 7-56
7.3.8.1 Research Needs 7-57
7.3.8.2 References 7-58
7.3.9 Wetland Treatment and Land Disposal of Urban Runoff 7-58
7.3.9.1 Research Needs 7-59
7.3.9.2 References 7-59
7.3.10 BMP Effectiveness 7-60
7.3.10.1 Research Needs 7-60
7.3.10.2 References 7-61
7.3.11 Improved Knowledge of Operating and Maintenance Costs 7-61
7.3.11.1 Research Needs 7-62
7.3.11.2 Reference 7-62

TABLE OF CONTENTS, CONT.

8.0 SYNTHESIS OF RESEARCH NEEDS AND CONCLUSIONS

8.1 Summary 8-1
8.2 Methods for Doing Research Needs Assessments 8-1
8.3 Purposes of Urban Wet Weather Research Program 8-2
8.4 Vision for the Benefits of Urban WWF Research 8-2
8.5 Summary of Research Recommendations 8-3
8.6 Sources and Monitoring 8-10
8.6.1 Automotive Pollution Source Reduction or Elimination 8-10
8.6.2 Source Control of Heavy Metals 8-10
8.6.3 Innovative Monitoring Methods 8-12
8.7 Receiving Water Impacts 8-12
8.7.1 Physical, Chemical, and Biological Responses in Receiving Waters 8-13
8.7.2 Defining Beneficial Uses for Urban Receiving Waters 8-13
8.7.3 Urban Stream and Sediment Geomorphology and Restoration 8-14
8.7.4 Wet Weather-Groundwater-Vadose Zone Impacts 8-14
8.8 Other Impacts 8-14
8.9 Management 8-15
8.9.1 Opportunities for Decentralized Wet Weather Management 8-15
8.9.2 Restructuring Federal Water Agencies to Better Address Urban Water Issues 8-15
8.10 Models and Decision Support Systems 8-16
8.10.1 Improve Stormwater Management Model to Include All Aspects of Contemporary Decision Support Systems 8-16
8.10.2 Incorporate Real-Time Control into Decision Support Systems 8-16
8.11 Watershed Management Linkages 8-17
8.12 Regulatory Policies and Financial Aspects 8-17
8.12.1 Determine Areas Where Regulatory Flexibility Can Achieve Watershed Goals 8-17
8.12.2 Innovative Financing Mechanisms for Wet Weather Controls 8-17
8.12.3 Improved Methods for Evaluating the Effectiveness of Public Education 8-18
8.13 Source Controls 8-18
8.13.1 Feasibility of Aggressive On-Site and Local Infiltration of Wet Weather Flows 8-18

R0025694

TABLE OF CONTENTS, CONT.

8.13.2	Feasibility of Using Porous and Permeable Pavements	8-19
8.13.3	Feasibility of Using Wet Weather Flows for Irrigation	8-19
8.14	Collection System Controls	8-19
8.14.1	Role of Separate and Combined Sewers Including Storage in Sewers	8-19
8.14.2	Deposition and Scour in Sewers	8-20
8.14.3	Improved Infiltration/Inflow Control Methods	8-20
8.14.4	Sewer Flow and Quality Monitoring	8-20
8.15	Storage/Treatment	8-20
8.15.1	High-Rate Wet Weather StorageTreatment Devices	8-20
8.15.2	High-Rate Operation of Wastewater Treatment Plants	8-21
8.15.3	Effectiveness of Best Management Practices	8-21
8.16	Estimated Cost of U.S. WWF R&D Program	8-21
8.17	References	8-23

PUBLICATION ORDER FORM
WERF SUBSCRIBERS

LIST OF TABLES

ES-1	Final List of Projects by Priority	ES-5
2-1	Urban Wet Weather Research Needs (Torno, 1986) (Prioritized)	2-3
2-2	Research Needs in Urban Stormwater Quality (Heaney, 1986) (Unprioritized)	2-4
2-3	Research Needs from 1990 WPCF Assessment (CH2M HILL, 1990) (Prioritized)	2-7
2-4	US EPA Wet Weather Research Program-Topics (Field et al., 1996) (Unprioritized)	2-8
2-5	Urban Wet Weather Flow Research Needs Developed by WERF and Representative of Bay Area Stormwater Management Agencies, August 21, 1996	2-11
2-6	WWF Research Needs Identified by Participants at the October 1996 WERF Workshop (Partially Prioritized)	2-13
2-7	Wet Weather Research Needs from the Engineering Foundation Malmö Conference, September 1997 (Unprioritized)	2-15
2-8	Research Needs in Urban Stormwater Quality—Composite List Cross-Referenced to the Individual Resrerch Needs Assessments	2-17
3-1	Research Needs for Characterization of Sources (Unprioritized)	3-5
4-1	Research Topics on Receiving Water Impacts (Unprioritized)	4-3
5-1	Research Topics on Urban Wet Weather Flow Management (Unprioritized)	5-4
5-2	A Variety of Urban Hydrologic, Hydraulic, and Water Quality Models (Huber, 1997)	5-6
6-1	Research Topics on Regulatory Policies and Financial Aspects of Urban Wet Weather Flow Management (Unprioritized)	6-2
6-2	Examples of Real Estate Premiums Charged for Property Fronting Urban Runoff Controls (Frederick et al., 1996)	6-28
6-3	Summary of Recommended CSO Performance Measures (AMSA, 1996)	6-29
6-4	Stormwater Environmental Indicators (Lindsey, Swietlick, and Hall, 1997)	6-30
7-1	On-Site Control Research Needs (Unprioritized)	7-3
7-2	Design Storm Frequencies for Minor and Macro Drainage Systems (ASCE/WEF, 1992)	7-3
7-3	Research Needs Identified for Collection Systems (Unprioritized)	7-26
7-4	Research Needs to Improve the Storage and Treatment (Unprioritized)	7-45
8-1	Composite List of Research Needs in Urban Stormwater Quality	8-4
8-2	List of Priority Projects	8-8
8-3	Final List of Projects by Priority	8-11
8-4	Needs for Publicly Owned Wastewater Treatment Facilities and Other Eligibilities (US EPA, 1997)	8-23

LIST OF FIGURES

3-1	Relative Mass Flow of Copper in Different Urban Drainage Systems (Boller, 1997)	3-2
4-1	Impacts and Stresses on Wetlands Caused by Urbanization (Hicks and Larson, 1996)	4-4
5-1	The Components of the NELUP DSS (Dunn et al., 1996)	5-7
5-2	Schematic Diagram of SHETRAN Flow Model (Dunn et al., 1996)	5-8
5-3	Creating an Input File, Selecting Cross-Section Profiles (Griffin, Bauwens, and Ahmad, 1994)	5-8
5-4	TVA Environment and River Resource Aid (TERRA) (Reitsma, 1996)	5-9
5-5	CSO Control Strategy Design Tools (Lavellee, Marcoux, and Bonin, 1996)	5-10
6-1	The Role of Engineered Treatment, Reclamation, and Reuse Facilities in the Cycling of Water through the Hydrologic Cycle (Asano and Levine, 1996)	6-10
6-2	Stormwater Handling Priority Diagram, Based on Sustainability, Proximity, and Visibility (Veldkamp et al., 1997)	6-13
6-3	Concept of Stormwater Reuse Residential Storage System (Heaney et al., 1998)	6-14
6-4	Mean Monthly Willingness to Pay to Avoid Particular Urban Water Supply Shortage Frequencies and Magnitudes (Hoag, 1997)	6-26
6-5	A Model of the Process of Measuring, Understanding, and Determining Possible Performance Criteria (Holmes, 1996)	6-27
7-1	Hierarchy of Objectives of Drainage Systems Showing Increasing Extent of Spatial and Temporal Effects (Butler and Parkinson, 1997)	7-4
7-2	Stormwater Handling Priority Diagram, Based on Sustainability, Proximity, and Visibility (Veldkamp, Hermann, and Colandini, 1996)	7-6

EXECUTIVE SUMMARY

This report presents the results of a national assessment of research needs in the management of urban wet weather flow. Three interrelated categories of urban wet weather flow management are covered: combined sewer overflows, sanitary sewer overflows, and urban wet weather flow discharges. The research needs assessment included the following steps: (1) extensive review of the literature; (2) review of previous research needs reviews, including US EPA's 1996 Wet Weather Flow (WWF) research program; (3) a one-day workshop to solicit ideas from interested professionals at the 1996 WEFTEC national meeting in Dallas; (4) extensive discussions with leading urban wet weather flow professionals; and (5) review of research needs with leading international experts.

The initial compilation of WWF research needs totaled 154 research projects. This list was reduced to 69 higher priority research projects, each summarized in one page. Each one-page summary consists of a statement on the importance of the problem including the relevant literature, research need(s), and key references. The final list of 26 topics is grouped into first and second priorities. Priority 1 topics, short- or long-term, should be initiated first. Priority 2 topics are also important but not as critical as the Priority 1 topics. In many cases, these final 26 topics are aggregations of the larger subset of priority research projects. Lastly, the final results of this needs assessment were organized into the following 10 categories (Table ES–1):

- Sources and monitoring;
- Receiving water impacts;
- Other impacts;
- Management;

- Models and decision support systems;
- Watershed management linkages;
- Regulatory policies and financial aspects;
- Source controls;
- Collection system controls; and
- Storage and treatment systems.

An estimated $20 million to $40 million per year would be needed to address the identified research needs.

The final list of priorities incorporates the following major principles and themes.

- WWF research provides an efficient way to bring innovations into the field in less time and thereby advance the state of knowledge in a more cost-effective and organized way.
- Source reduction or elimination, where possible, accompanied by treatment, provides a long-term, sustainable solution to WWF problems. A mass and energy balance approach is needed to characterize the nature of contaminants entering WWFs and to decide how best to manage them.
- The automobile is a major source of urban WWF problems and warrants special study of its overall impact.
- It is essential to evaluate all results of WWFs and to integrate these public health, physical, chemical, biological, socioeconomic, financial, and other considerations into an evaluation framework.

- Management of sediments associated with WWFs is a vital part of the management strategy.

- Subsurface impacts on groundwater and the vadose zones are becoming more of an issue in areas that are promoting infiltration as a management strategy.

- Innovative management strategies that are more compatible with bottom–up integrated watershed management must be developed.

- The US EPA Stormwater Management Model (SWMM) should be updated and expanded into a user friendly decision support system that interfaces with geographic information systems (GIS), relational database management systems, process optimizers, risk analysis capabilities, real-time control capabilities, and an expanded engine to incorporate other components of urban water systems.

- Real-time control provides an overarching framework for a data-centered approach for future WWF management.

- Methods are needed to integrate management of urban WWFs and watershed management.

- Policy research is needed to evaluate the feasibility of providing regulatory flexibility within a traditional command and control legislative framework that is regulated by individual media and individual constituents.

- Financing local WWF management programs is a challenge because of their multipurpose nature.

- Water quality standards issues related to wet weather flows must be reevaluated.

- Documented cases are needed of "success stories" of how a high level of environmental quality would enable communities to make their waterways focal points of redevelopment.

- On-site and local infiltration systems, including porous and permeable pavements, should be carefully evaluated for U.S. conditions, at the same time considering international experience.

- On-site and local wet weather flow re-use systems should be evaluated with particular attention to re-use for irrigation and cooling water.

- Innovations are needed in collection system design and operation including life cycle costing to avoid short-sighted approaches that reduce initial costs but leave a legacy of greatly increased operating costs. Unconventional sewer systems and flushing systems should be evaluated.

- More rigorous methods are needed to evaluate the efficacy of storage and treatment and other BMPs. Appropriate monitoring and modeling are essential components of these methods.

Table ES-1. Final List of Projects by Priority

Topic	*Priority*	
Sources and Monitoring		
Automotive pollutant source reduction or elimination	1	
Source control of heavy metals		2
Innovative monitoring methods	1	
Receiving Water Impacts		
Improved understanding of the physical, chemical, and biological processes		2
Defining beneficial uses for urban receiving waters		2
Urban stream and sediment geomorphology and restoration	1	
Stormwater-groundwater-vadose zone impacts		2
Other Impacts		
Evaluation of other performance measures for wet weather flow systems	1	
Management		
Opportunities for decentralized urban wet weather management	1	
Restructuring federal water agencies to better address urban water issues		2
Models and decision support systems		
Improve SWMM to include all aspects of contemporary decision support systems	1	
Incorporate real-time control into decision support systems	1	
Watershed Management Linkages		
Participate in integrated long-term experimental evaluation of urban watersheds	1	
Regulatory policies and financial aspects		
Determine areas where regulatory flexibility can achieve watershed goals		2
Innovative financing mechanisms for wet weather controls		2
Improved methods for evaluating the effectiveness of public education		2
Source Controls		
Feasibility of aggressive on-site and local infiltration of wet weather flows	1	
Feasibility of using porous and permable pavements		2
Feasibility of reusing wet weather flows for irrigation	1	
Collection System Controls		
Evaluation of role of separate and combined sewers including storage in sewers	1	
Deposition and scour in sewers		2
Improved infiltration/inflow control methods	1	
Benefits of sewer flow and quality monitoring		2
Storage and Treatment		
Improved high-rate wet weather storage treatment devices	1	
High-rate operation of wastewater treatment plants	1	
Effectiveness of best management practices	1	
TOTAL	15	11

Acronyms and Abbreviations Used in this Report

AF	acre-feet
AGNPS	agricultural nonpoint source
AMSA	Association of Metropolitan Sewerage Agencies
ARMA	autoregressive moving average
ASCE	American Society of Civil Engineers
ASDM	atmospheric and sediment deposition model
AWRA	American Water Resources Association
BMP	best management practice
BOD	biochemical oxygen demand
BOD_5	5-day BOD
CD	compact disk
CDM	Camp Dresser and McKee, Inc.
COD	chemical oxygen demand
CSO	combined sewer overflow
CSUDP	Colorado State University Dynamic Programming
CWA	Clean Water Act (U.S.)
CWNS	Clean Water Needs Survey
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DSS	decision support system
EA	environmental assessment
EDTA	ethylenediaminetetraacetic acid
EFAB	Environmental Financial Advisory Board (US EPA)
ERC	Environmental Research Center
ET	evapotranspiration
ETV	environmental technology verification
EXTRAN	extended transport model
FEMA	Federal Emergency Management Agency (U.S.)
FHWA	Federal Highway Administration (U.S.)

GB	Great Britain (U.K.)
GAC	granular activated carbon
GAO	U.S. General Accounting Office
GCM	global climatic model
GIS	geographic information system
GUI	graphical user interface
HEC	Hydrologic Engineering Center
HMS	hydrologic management system (replaces HEC-1)
I/I	infiltration/inflow
IAHR	International Association for Hydrologic Research
IAWQ	International Association for Water Quality
LTER	long-term ecological research
MCRS	minimum cost remaining savings
MTBE	methyl tert-butyl ether
NEPA	National Environmental Policy Act (U.S.)
NEXGEN	next generation
NOAA	National Oceanographic and Atmospheric Administration (U.S.)
NPDES	National Pollution Discharge Elimination System (U.S.)
NPS	nonpoint source
NSF	National Science Foundation (U.S.)
NTIS	National Technical Information Service (U.S.)
NURP	Nationwide Urban Runoff Program (US EPA)
O&M	operating and maintenance
PAH	polycyclic aromatic hydrocarbon
PC	personal computer
PET	potential evapotranspiration
R&D	research and development
RAS	river analysis system (replaces HEC-2)

RTC	real-time control
SCADA	supervisory control and data acquistion system
SCRB	separable cost remaining benefits
SCS	Soil Conservation Service (U.S.)
SS	suspended solids
SSO	sanitary sewer overflow
ST	storage treatment
SWMM	stormwater management model
TIN	triangular irregular network
TMDL	total maximum daily load
TSS	total suspended solids
TVA	Tennessee Valley Authority
U.S.	United States
U.S. COE	U.S. Army Corps of Engineers
US EPA	U.S. Environmental Protection Agency
UAA	use attainability analysis
U.K.	United Kingdom
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	ultaviolet light
WEF	Water Environment Federation
WEFTEC	Water Environment Federation Technical Exhibition and Conference
WERF	Water Environment Research Foundation
WPCF	Water Pollution Control Federation (predecessor of WEF)
WWF	wet weather flow
WWTP	wastewater treatment plant

CHAPTER 1.0

INTRODUCTION

1.1 The Problem and Opportunities

Proper management of the quantity and quality of urban wet weather flow remains a major environmental problem. Estimated control costs for the United States range from several billion to hundreds of billions of dollars. The variation in these cost estimates stem from the magnitude of the source, the effectiveness of the controls, and the expected impacts on receiving water. On the positive side, communities that have successfully managed their water quality problems are now enjoying revitalized urban areas where receiving waters are major assets to the community, not perceived solely as components of the drainage and wastewater transport facilities. Cost-effective urban stormwater quality management should be integrated with urban stormwater quantity management and urban water management in general. Ideally, the urban water management system should be integrated with watershed management to take advantage of multipurpose opportunities. Urban wet weather flows come from three sources: combined sewer overflows (CSOs), sanitary sewer overflows (SSO), and stormwater discharges from storm sewers.

1.2 Intended Audiences for this Research Needs Assessment

The intended audiences for this wet weather flow (WWF) research assessment include the following:

- The local user community that supports WERF;
- Federal agencies including US EPA, NSF, COE, Federal Highways, FEMA, and other agencies involved with urban WWFs;
- The WWF research community in universities and other organizations;

- The WWF professional and research community, which is addressing many of the key issues defined in this research needs assessment; and

- People outside this field whom we hope to interest in addressing these important questions

1.3 Vision for the Benefits of Urban WWF Research

Concerted efforts since the late 1960s to clean up urban wastewater and stormwater have achieved impressive results. Previously, the accepted fate of urban watercourses was to serve as recipients of the unwanted by-products of urbanization including dry weather and stormwater-transported wastes from urban areas, in addition to receiving runoff from various industrial, agricultural, silvicultural, mining, and other activities. Also, these same receiving waters were ditched, drained, sewered, and subjected to a wide variety of manipulations to serve human needs. In addition to water quality changes, these waters underwent severe hydrologic changes due to hydropower development, navigation, water supply, flood control, recreation, etc. The end product of all of these abuses to our receiving waters was that citizens were conditioned to think of their waterways as undesirable kidneys of the city to be hidden and avoided.

Following the expenditure of billions of dollars on water quantity and quality improvements, we are beginning to see the long-term fruits of these investments. For example, the South Platte River flows through Denver from south to north. The South Platte has been subjected to virtually everu human influence. It is dammed upstream for water supply, hydropower, and flood control. Much of its flow is diverted for off-stream uses. Prior to modern water quality programs, the South Platte received poorly treated sewage, combined and separate sewer overflows and stormwater runoff, industrial wastes including meat packing wastes, and a variety of other insults. However, following aggressive cleanup and rehabilitation programs the South Platte switched from being a public health problem to a highly prized urban asset. The City of Denver is currently constructing a $60 million greenway along the entire stretch of the South Platte through Denver. Completed sections of this stream rehabilitation have stimulated major urban redevelopment in Denver with concurrent rapidly escalating property values along the South Platte because of its desirability as a recreational resource (swimming, fishing, boating) and as a vital link in the bicycle and pedestrian corridor through the city. Success stories, such as Denver's, are prompting many other communities and neighborhoods to integrate water into their overall plans for the future. This is the promise and vision for controlling WWFs. They are the last major uncontrolled source of pollution to our receiving waters. If we can manage this pollution source and provide a desirable hydrology for receiving waters, citizens can fully enjoy the benefits of this important investment for themselves and for posterity.

1.4 Preview of the Remainder of the Report

The next chapter of this report reviews previous research needs assessments and offers a vision for the expected gains from additional research. Individual research needs chapters give source characterization (Chapter 3.0), receiving water impacts (Chapter 4.0), management (Chapter 5.0), regulatory policies and financial aspects (Chapter 6.0), and control technologies (Chapter 7.0). One-page summaries of research needs are presented for each identified problem. The summaries are divided into three sections: statement of the problem, description of the research need(s) in this area, and key references. In the concluding Chapter 8.0, the 69 identified research needs topics are combined into 26 topics listed as priority 1 or 2. Lastly, we estimate the total cost of meeting these needs.

CHAPTER 2.0

PREVIOUS WET WEATHER FLOW RESEARCH NEEDS ASSESSMENTS

2.1 Literature Review

The literature review for the research needs assessment incorporates previous research needs assessments and their associated literature reviews. CH2M HILL (1990) summarized much of the literature as part of their research needs assessment. Also, the ASCE/WEF *Manual of Practice* (1992; 1998) and books by Debo and Reese (1995) and Novotny and Orem (1994) provide the reader with an overview, of the state of the art including extensive literature reviews. Field et al. (1997a, b) thoroughly review the wet weather flow (WWF) research results published in 1996. James (1996) edited a book of 18 papers dealing with the modeling aspects of urban stormwater. These papers address a variety of topics including the use of the models themselves, data management including GIS, and the interrelationships between BMPs and water quality. The two-volume proceedings of RIVERTECH96 (Maxwell, Pruel, and Stout, 1996) contains many papers related to urban stormwater management. The proceedings from a national conference on sanitary sewer overflows (SSOs) provide information on SSO problems generally and infiltration and inflow problems in particular (US EPA, 1996). The proceedings of the seventh international conference on urban storm drainage, held in Hannover, Germany, comprehensively describe new developments throughout the world (Sieker and Verworn, 1996; 1997). James (1997) edited a book of 28 papers on urban WWFs including a CD with 4,000 titles related to WWFs. The September 1997 Engineering Research Foundation Conference on Innovative Urban Stormwater Management, held in Malmö, Sweden, offers information on research needs (Rowney, Stahre, and Roesner, 1998).

2.2 Wet Weather Flow Research

Urban WWF quantity and quality has been studied since the late 1960s, initial interest focusing on combined sewer overflows. The US EPA Municipal Environmental Research Laboratory's Storm and Combined Sewer Program invested $60 million to $70 million in some 250 extramural projects until 1981 (Field 1982). The US EPA Nationwide Urban Runoff Program (NURP) sponsored $30 million in field studies in 28 cities between 1979 and 1983 (US EPA, 1983). Other federal agencies including the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the Office of Water Research and Technology also had active urban stormwater research and demonstration programs during the 1970s. While the exact total remains uncertain, federal investment in stormwater research prior to 1983 probably exceeded $100 million. Subsequently, wet weather research funding by federal agencies in the United States disappeared in the early 1980s and has only recently begun to reemerge. This 15-year hiatus caused many gaps in U.S. research. Meanwhile, significant research efforts continued in Europe, Australia, Japan, and other foreign counties (Marsalek and Sztruhar, 1994). Thus, we must look to the international community to assess the current state of the art.

Roesner and Traina (1994) cite estimates of the American Public Works Association (1992) of urban stormwater control costs in the United States ranging from $147 million to $407 billion in capital costs and $1.2 biollion to $542 billion/year in annual O&M costs depending upon the assumed level of BMP control. Recently, the US EPA (1997) published results of the 1996 needs survey for wastewater and stormwater systems. This needs assessment estimated only the expected total cost of controlling combined sewer overflows. It gave partial estimates for sanitary sewer overflows (SSOs) and stormwater runoff. A rough estimate of wet weather control costs based on the 1996 needs survey and preliminary guesses at the cost of managing SSOs and urban stormwater yields a capital investment of $100 billion with annual O&M costs of $10 million per year.

The National Research Council (1993) evaluated future directions of wastewater management in coastal areas. Their report describes how a holistic approach can be taken to urban wastewater problems including wet weather flows. General research recommendations are related to improved source characterization, control effectiveness, and receiving water impact assessment.

2.3 Previous Research Needs Assessments

2.3.1 1986 Compilation by Torno

Torno (1986) summarized stormwater research needs as developed by conferees at an international conference on urban stormwater. The participants assigned priorities to the results of this assessment (Table 2–1) by voting. The number of votes received by each topic is presented in the right-hand column. The highest priority research topic was to conduct additional research to improve understanding of the processes of pollutant accumulation and transport in urban runoff. A total of 17 topics were selected, but not categorized.

Table 2–1. Urban Wet Weather Research Needs (Torno, 1986) (Prioritized)

No.	*Research Topic*	*No. of Votes*
1	The understanding of the processes and mechanisms, including the related mathematical models of pollutant accumulation and transport in urban runoff.	13 votes
2	The impacts of metals and other toxic pollutants on aquatic biota, including the means to monitor these impacts.	8 votes
3	The impacts of urban runoff pollution on receiving waters, including the impairment of beneficial uses. This includes the modeling of these impacts.	8 votes
4	Better understanding of the processes of sedimentation and scour of solid particles in sewers.	8 votes
5	Development of standards for sampling, analysis and data reporting for urban runoff pollutants.	8 votes
6	Performance of stormwater and combined sewer overflow treatment devices.	7 votes
7	The economic and institutional impacts of pollution control programs.	6 votes
8	The development of stormwater and combined sewer overflow discharge criteria based on receiving water impacts.	6 votes
9	The operation and maintenance of sewer and control technology systems, including the effects of O&M on system performance.	5 votes
10	The impacts of infiltrated urban runoff on groundwater.	4 votes
11	Improved techniques for rainfall forecasting, including the use of radar.	4 votes
12	Identification of sediment/water interactions in sewers and receiving waters.	4 votes
13	Identification and quantification of sources of error and uncertainty in model results.	3 votes
14	Development of criteria for model calibration and verification.	3 votes
15	The effects of real-time control systems on system performance and improved water quality.	3 votes
16	Case studies where complete planning, design, construction, O&M of storm and combined sewers demonstrate impacts on receiving water quality.	3 votes
17	Impacts of stormwater and combined sewage on the performance of wastewater treatment facilities.	3 votes

2.3.2 1986 Research Needs Assessment by Heaney

Under US EPA sponsorship, Heaney (1986) summarized research needs in urban stormwater pollution including the results of earlier studies of research needs. This assessment used an extensive literature review and informal contacts with leading experts in the field to develop the final list of 52 topics shown in Table 2–2. These topics were not ranked.

Table 2–2. Research Needs in Urban Stormwater Quality (Heaney, 1986) (Unprioritized)

No.	*Description*	*No.*	*Title*
1	**Sources**		
	Runoff Quantity	1	Relationship of runoff and basin structure
		2	Linkage of surface and subsurface phenomena
		3	Use of dense rain gages to describe storm patterns
		4	Integrate GIS to refine spatial analysis capabilities
		5	Flow meters to measure widely variable flows
	Runoff Quality	6	Flow-weighted sampling devices for variable flows
		7	Influence of land use on water quality
		8	Methods to distinguish wet and dry weather flows in combined sewers.
2	**Controls**		
	On-site	1	Effectiveness of swales
	Collection Systems	2	Instrumentation & monitoring to evaluate sewer hydraulics
		3	Cost-effective ways to rehabilitate & replace old sewers
		4	Laboratory & field studies of deposition & scour in sewers
		5	Use of simulation models in storm sewer design
		6	Calibration of transport models using improved databases
	Downstream Controls	7	Laboratory studies of high-rate treatment systems
		8	Effectiveness of disinfection with highly variable flows
		9	Design of storage/release systems to maximize pollutant control
		10	Evaluation of groundwater injection systems
		11	Engineering considerations in using wetland systems
		12	Application rates for land disposal of urban runoff
		13	Reuse of urban runoff as cooling water
		14	Probabilistic performance criteria for wet weather controls
		15	Treatment of heavy metals in urban runoff

Table 2-2, cont. Research Needs in Urban Stormwater Quality (Heaney, 1986) (Unprioritized)

No.	*Description*	*No.*	*Title*
		16	Sludge/solids disposal aspects of control options
		17	Process control systems to optimize performance of control
3	**Receiving Water Impact**		
	Quantity	1	Hydrograph separation techniques to estimate the origin of flow in rivers
	Quality	2	Quantify benefits of stormwater quality control
		3	Bioassay procedures for short-term intermittent exposures to urban runoff
		4	Bioassay procedures for long-term exposures to heavy metal accumulation in benthos
		5	Mass balance of urban runoff and receiving water fluxes
		6	Criteria for wet weather quality standards
		7	Behavior of urban runoff in mixing zones of rivers, lakes, & estuaries
4	**Institutional Arrangements**	1	Preparing effective and implementable NPS regulations
		2	Establish a mechanism for coordinating stormwater research across various funding agencies
5	**Watershed Management**	1	Understanding regional differences in receiving waters
	Linkages	2	Watershed response during winter conditions
		3	Watershed-based water quality standards
		4	Develop long-term watershed case studies
		5	Develop a watershed assessment methodology
		6	Feasibility of identifying "natural conditions" at the watershed scale
		7	Establish a network of urban research catchments
6	**Decision Support &**	1	Development of more robust parameter estimation methods
	Modeling	2	Add solids handling to simulation models
		3	Interface simulation and optimization models
		4	Refine statistical methods as preliminary screening procedures for simulation models
		5	Perform detailed statistical analyses of existing, NURP, U.S.GS, and other data
		6	Combine available databases into a single database

Table 2-2, cont. Research Needs in Urban Stormwater Quality (Heaney, 1986) (Unprioritized)

No.	Description	No.	Title
		7	Develop methods to properly allocate the costs of multi-purpose water projects
		8	Apply recently developed methods for evaluating public response to alternative control programs
		9	Develop user friendly integrated decision support systems
		10	Methods for estimating the probability distributions of sewage, urban runoff, and upstream flows
	Total no. of topics	52	

2.3.3 1990 WPCF Research Needs Assessment

WERF's predecessor, the Water Pollution Control Federation Research Foundation, sponsored a 1990 research needs assessment of nonpoint pollution (CH2M HILL, 1990). This assessment included agricultural and mining wastes in addition to urban runoff. The resulting 17 priority-assigned topics are shown in Table 2–3. The 1990 WPCF assessment reflected the emerging interest in watershed approaches. The other difference was in the interest in PAHs.

2.3.4 US EPA Research Needs Assessment

Shortly before this project began, US EPA released a draft of its urban wet weather flow (WWF) research plan for review (Field et al. 1997a). This major effort was reviewed by various groups including ASCE's Urban Water Resources Research Council (UWRRC). Several UWRRC members are also involved in this research needs assessment. Thus, the US EPA draft provided an excellent opportunity to involve a larger audience in the research needs process. It also heightened interest in the process because of the growing optimism that US EPA's WWF research program was being revitalized.

The final list of 77 projects (Table 2-4) were not assigned priorities. The US EPA divided the topics into the following five categories: characterization and problem assessment (13 topics); watershed management (16 topics); toxic substances impacts and control (5 topics); control technologies (36 topics); and infrastructure improvement (7 topics). However, many of them overlap, e.g., the Rouge

River Restoration, is a large demonstration project that encompasses virtually all areas. Many of these topics include a large technology transfer component. The US EPA WWF document was compiled by the Urban Watershed Management Branch of US EPA's National Risk Management Research Laboratory. This group is the designated lead in the WWF area. However, other EPA research organizations also participate in this program including (Field et al. 1996):

- Microbial Contaminants Control Branch
- Treatment Technology Evaluation Branch
- Water Quality Management Branch
- Subsurface Protection and Remediation Division
- Technology Transfer and Support Division.

Table 2–3. Research Needs from 1990 WPCF Assessment (CH2M HILL, 1990) (Prioritized)

No.	*Research Need*
1	Probabilistic performance criteria for wet weather controls
2	Improved knowledge of O&M costs
3	Determine decomposition rates for various PAHs
4	Bioassay procedures for long-term exposure to heavy metal accumulation in benthos
5	Mass balance of urban runoff and receiving water fluxes
6	Impact of snowmelt on receiving water quality
7	Establish a mechanism for coordinating stormwater research across various funding agencies
8	Understanding regional differences in receiving waters
9	Watershed responses during winter conditions
10	Watershed-based water quality standards
11	Feasibility of defining "natural' conditions at the watershed scale
12	Establish a network of urban research catchments.
13	Develop more robust parameter estimation methods
14	Add solids handling to simulation models
15	Develop user friendly integrated decision support systems
16	Methods for evaluating NPDES data
17	Methods for estimating the probability distributions of sewage, urban runoff, and upstream flows

Table 2–4. US EPA Wet Weather Research Program-Topics (Field et al., 1996) (Unprioritized)

Research Area & ID	*Title*
1.0 Characterization and Problem Assessment	
1.1	Disinfection/Pathogen Detection
1.2	Fecal Contamination
1.3	CSO Monitoring
1.4	Receiving Water Impacts
1.5	WWF Physical Stressors
1.6	Urban Landfill Pollution
1.7	Small Stream Impacts
1.8	Large River Pollution
1.9	Evaluation of Health Risks
1.10	Waterbody Impacts Model
1.11	Fate of Nitrogen Inputs
1.12	Influences of Land Use
1.13	CSO Disinfection
2.0 Watershed Management	
2.1	Watershed Management
2.2	New Urban Areas
2.3	Watershed Modeling
2.4	Source Water Protection
2.5	Stormwater Reuse
2.6	Stormwater—Groundwater Interactions
2.7	Natural Attenuation
2.8	Vadose Zone
2.9	Atmospheric Deposition
2.10	Mill Creek Watershed Plan
2.11	Catoma Creek Watershed Plan
2.12	Stormwater Controls/Impacts
2.13	Watershed Model—Case Study
2.14	Watershed Ecosystem Model
2.15	Information Repository
2.16	Sediment Impacts & Control
3.0 Toxic Substances Impacts and Control	
3.1	Toxics' Characterization/Treatment
3.2	Toxics' Testing/Assessment
3.3	Toxics' Pollution Prevention
3.4	Natural Fiber Filtration
3.5	Toxics' Risk Reduction

Table 2–4, cont. US EPA Wet Weather Research Program-Topics (Field et al., 1996) (Unprioritized)

Research Area & ID	*Title*
4.0 Control Technologies	
4.1	Rouge River Restoration
4.2	BMP Manual
4.3	Industrial Runoff Control
4.4	Management for Small Communities
4.5	Roadway/Airport Deicing
4.6	BMP Design/Effectiveness
4.7	Urban BMP Effectiveness
4.8	Runoff Control Using Compost
4.9	Riparian Forest Management
4.10	CSO Measures of Success
4.11	Flow Balance Method
4.12	Storm Inlet Device
4.13	Stormceptor's Inlet Device
4.14	CDS stormwater Treatment
4.15	Cross Connection Identification
4.16	Storage Facilities Design Manual
4.17	Real-Time Control by Radar
4.18	CSO Vortex Controls
4.19	High-Rate Sedimentation
4.20	Magnetic Separation
4.21	WWF Design Protocols
4.22	Retrofitting Control Facilities
4.23	CSO Concepts for stormwater
4.24	SSO Corrective Action
4.25	WWF Effectiveness Protocols
4.26	Vortex/Disinfection Treatment
4.27	Crossflow Plate Settlers
4.28	High-Rate Disinfection
4.29	Demonstration of Biofilters
4.30	High-Rate Ozonation
4.31	Triple Purpose Storage
4.32	Harlem River Wetlands
4.33	Storage/Wetlands Treatment
4.34	Constructed Vegetative Treatment Cells
4.35	ETV Pilot for WWF Controls
4.36	Sewer and Tank Sediment Flushing

Table 2-4, cont. US EPA Wet Weather Research Program-Topics (Field et al., 1996) (Unprioritized)

Research Area & ID	*Title*
5.0 Infrastructure Improvement	
5.1	Infrastructure Rehabilitation
5.2	Sewer Maintenance Effectiveness
5.3	Sewer Maintenance Optimization
5.4	Sanitary Sewer System Design
5.5	House Service Laterals
5.6	Reduced Impervious Cover
5.7	Swales Instead of Curbs

In addition to intra-agency coordination, US EPA coordinates with other federal agencies (e.g., Corps of Engineers), professional societies (e.g., ASCE, WEF), and international organizations (e.g., International Association for Hydraulic Research, International Association of Water Quality). Thus, a good infrastructure exists for coordinating research activities with the appropriate research and user communities.

Notable shifts in emphasis since the 1990 research assessment were the continuing growth of emphasis on watershed approaches, risk management, and toxics characterization and control.

2.3.5 1996 WERF/Bay Area Stormwater Management Agencies Wet Weather Research Needs Assessment

At the same time US EPA released its draft research needs document, WERF met with representatives of the Bay Area Stormwater Management Agencies to identify wet weather research needs. The 25 wet weather research needs, without priorities, are listed in Table 2-5.

This research needs assessment emphasizes the need to understand regional differences, e.g., technology applied in the Eastern United States does not necessarily perform well in the more arid Western United States. It also recommends a reevaluation of the environmentally friendly developments instituted during the past 30 years. Have they worked well? This needs assessment introduces the issue of environmental justice and how benefits and costs of these programs affect various socioeconomic groups.

Table 2–5. Urban Wet Weather Flow Research Needs Developed by WERF and Representative of Bay Area Stormwater Management Agencies, August 21, 1996 (Unprioritized)

No.	*Research Need*
1.	Acceptance of Eastern data in the West
2.	Hydraulic control BMPs
3.	Dry cycle contamination (agricultural issue)
4.	Atmospheric deposition
5.	BMP maintenance
6.	Biological indicators
7.	Can sand filters and other Eastern technologies work for Western storms?
8.	Limiting factors for ecosystems
9.	Better indicators of actual fecal contamination
10.	Impacts of BMPs
11.	Link decision making processes to quality measures: what is achievable given a particular degree of authorization?
12.	Characterization of non-stormwater impacts (cooling water pools, etc.)
13.	Vegetative management practices
14.	Environmental friendly development assessment: 20 years later
15.	Cross-media issues (e.g., Hg); pollutant cycling and how to break the cycle
16.	Sediment quality
17.	Dioxin/PCBs
18.	Turbidity studies, settleability, particle sizes, etc.
19.	Monitoring strategies for multiple point sources
20.	First flush impacts in the West
21.	Public perception; linking beneficial uses with the optimal distribution of funds
22.	Aquatic and non-aquatic vegetative management (e.g., techniques for killing algae in intake pipes)
23.	Distributing funds in developed and developing areas; "environmental justice"
24.	BMP cost-effectiveness
25.	Pesticide transport

2.3.6 October 1996 WERF WWF Research Needs Workshop, Dallas, Texas

Shortly after this project was initiated in September, 1996, a one-day workshop was held in Dallas on October 5 as part of the 1996 WEFTEC national meeting. Approximately 60 people participated.

Many of the participants had reviewed the US EPA Research Needs draft. Attendees received background information in an overview report entitled "Wet Weather Research Assessment." The format for the workshop was a series of presentations on the various aspects of urban stormwater management. In addition, Simon Clarke gave an overview of wet weather research in Great Britain and Don Weatherbe gave a similar overview of recent research in Canada. During the afternoon, all participants joined one of the four following groups: Wet Weather Sources; Controls; Receiving Water Impacts; or Institutional Arrangements, Watershed Management Linkages, and Decision Support and Modeling. During the final session, each group presented its topics and how it would assign priority to them. Most workshop participants represented the user community. The final results from this effort are shown in Table 2–6.

While the WERF workshop reiterated many of the research needs expressed in earlier needs assessments, some different themes were emerging. With regard to source characterization, there was significant interest in gaining a better understanding of the overall impactof the automobile including the need for increasing impervious area and pollutant load generation. Also, construction practices and litter control were topics of considerable interest. On the control side, there was strong interest in a more integrated approach to control effectiveness rather than examining each control in isolation. Another major shift in focus was a strong recommendation on the need for research directed to providing the technical and policy basis for more flexible regulatory programs. These recommendations are compatible with efforts within US EPA to reinvent itself to provide this additional flexibility. But, this is not an easy task for an agency whose entire history is based on regulating specific constituents in individual media (Government Accounting Office, 1997).

2.3.7 Recommendations from the 1997 Malmö Conference

Wet weather research needs were assessed as part of the Engineering Foundation Conference entitled Innovative Urban Water Management for the 21st Century, held in September 1997 in Malmö, Sweden (Rowney, Stahre, and Roesner, 1998). This week-long conference attracted 95 leading stormwater experts from throughout the world. Several suggestions for research needs emerged from the papers and discussions. Also, the senior author of this report organized an afternoon session on research needs with 16 attendees, most of whom are academics. Following a briefing on the ongoing WERF project, the attendees were asked to make their suggestions. Table 2–7 summarizes the results. The suggestions are not listed in any particular order.

Table 2–6. WWF Research Needs Identified by Participants at the October 1996 WERF Workshop (Partially Prioritized)

No.	*Sources*	*Votes*
1	Automotive fate and transport of inputs to water environment	8
2	Construction materials and practices	4
3	Litter generation, transport, fate, and control effectiveness	2
4	Improved methods of source controls	3
5	Buildup and washoff processes	2
6	Atmospheric deposition	
7	Urban drainage design improvements	
8	Ultimate fate of pollutants captured by BMPs	
9	Rainfall-runoff for small storms-micro-storm management	
10	Modifying urban surfaces to reduce hydraulic and pollutant loads	
11	How to measure and evaluate pathogens in stormwater	
12	Runoff quality monitoring protocols.	
13	Thermal pollution associated with urbanization.	
14	Isotope tracking techniques for characterizing the nature of WWFs	
15	WWFs from industrial sites	
16	Basic processes of buildup and washoff in developed urban areas.	
No.	*Controls*	*Votes*
	Most of the individual topics were subsumed under the first category	
1	Unified design protocols including local hydrology, catchment and water quality characteristics, performance measures, controls, stream impacts, and system optimization.	16
2	Trash, floatables control	7
3	Control of suspended solids	3
4	Integrated systems of flood and pollution control including reuse	
5	Collection systems	
	Rehabilitation	
	New designs for new areas:	
	Collection systems as reactors	
	Demonstration of sewer flushing	
	In-system storage	
	Real-time control	
6	Dissolved solids removal	

Table 2–6, cont. WWF Research Needs Identified by Participants at the October 1996 WERF Workshop (Partially Prioritized)

No.	*Institutional Arrangements, Watershed Management Linkages, & Decision Support Systems*	*Votes*
1	To identify those areas where it makes sense and is feasible for EPA to provide regulatory flexibility to achieve watershed goals. Possible areas: Compliance schedules Permitting innovations. Redefining water quality standards and metrics. Foster local accountability.	13
	Rationale: Current regulatory program is not consistent with the nature of the problem.	
2	To determine the costs/performance function data for stormwater controls as a function of operation, maintenance, and replacement costs. Rationale: Necessary to accurately project costs and benefits. Natural reluctance to spend money on maintenance. However, maintenance is essential to attain design objectives.	17
3	How do local governments make appropriate decisions to develop watershed? management/regulatory programs that will "withstand the test of time" and that all parties will buy into? Decision support tools Feedback on public involvement, participation techniques How to translate public desires into action? Common elements of successes and failures. Characterize and prioritize the factors that lead to "environmental integrity." Rationale: Without this approach, defer either to federal mandates or local political decsions.?	
No.	*Receiving Water Impacts*	*Votes*
1	If watershed is urbanized and changes in hydrology occur, what will the stream look like?	15
2	What are human health risk/ecosystem impact trade-offs?	8
3	What indices are needed to determine specific impacts of constituents, e.g., metals, BOD, pathogens?	3

With a theme of innovative urban water management for the 21st century, the Malmö conference was an ideal venue for receiving ideas for research. A major theme that emerged from the conference was the need to develop interdisciplinary teams that include engineers, scientists, landscape architects, and planners to develop new or redeveloped urban systems. As such we need to move away from the narrow view—especially in the United States—of forcing these urban developments to conform to narrowly focused regulations on how stormwater should be managed. Numerous case studies were presented by landscape architects showing how functional and beautiful designs could be developed with participation from all affected stakeholders.

Table 2–7. Wet Weather Research Needs from the Engineering Foundation Malmö Conference, September 1997 (Unprioritized)

No.	*Research Need*
1	Endpoints of toxicants in detention ponds
2	Need source control of toxics in automobiles, e.g., brake pads. Long-term solution is source control
3	Real-time control linking collection, treatment, and receiving waters
4	Integrating landscape architecture into urban water management programs. How to develop designs that show the beauty and spirituality, as well as the function of water in urban areas. Goal is not necessarily to make water system look "natural"
5	Develop improved decision support systems with better simulation engines, direct links with optimization techniques, explicit inclusion of RTC, and that incorporate sustainability and risk analysis
6	Long-term sustainability of infiltration systems. More efficient data collection techniques including transmission hardware and software are needed
7	Better understanding of health impacts of urban runoff
8	Better methods to quantify benefits of urban stormwater management
9	Groundwater pollution from highways
10	Quality of roof runoff and its fate in soil systems. Change roofing materials. Impact of grassed roofs
11	Development of stochastic models for urban stormwater
12	Measurements to track the movement of toxics through urban areas
13	Development of environmental ethics to reduce litter
14	Adaptive real-time control for entire urban water system including water supply, wastewater, and stormwater
15	Improve EPA use attainability studies to reflect the desire to provide innovative, flexible approaches to water quality management
16	Better define ecosystem-flow contaminant relationships for urban stormwater management
17	Cradle to grave tracking of urban water pathways and controls
18	Biofilm processes and biofiltration
19	Integrated urban water systems evaluation
20	Long-term performance of wetlands and ponds
21	Short and long-term performance of porous and permeable pavement systems. Need to support continuing experimental and laboratory studies
22	Techniques for reducing the demand for automobile travel, e.g., now pay a toll for entering Trondheim, Norway and Cambridge, England
23	Alternatives to current urban water management systems. Want to develop more sustainable systems. Need interdisciplinary teams
24	Urban stormwater management in cold climates

Table 2–7, cont. Wet Weather Research Needs from the Engineering Foundation Malmö Conference, September 1997 (Unprioritized)

No.	*Research Need*
25	Develop long-term experimental watersheds in urban areas. Australia has one that has been operated for 20 years. Hannover has one with 5 to 6 years of data. The new Munich project includes long-term monitoring.
26	Investigate the feasibility of decentralized urban water management and privatization. Use Great Britain, Australia, and New Zealand as case studies
27	Support large-scale international effort to evaluate the feasibility of sustainable urban water systems including careful consideration of demand management, recycling and reuse, and water management at the individual and neighborhood levels

Another striking observation from the U.S. perspective is the widespread use of stormwater infiltration systems in other parts of the world, e.g., Tokyo and many areas in Europe. These infiltration systems are able to totally contain smaller storms on site and reduce the impacts on local receiving waters. Another strong trend is the much more aggresive use of water reuse internationally. Finally, the amount of urban stormwater research in Europe greatly exceeds current activities in the United States. We need to learn from our international colleagues.

2.3.8 Compilation of Research Needs Efforts

The previous sections summarized the following seven research needs assessments:

- Assessment by international experts (Torno, 1986)—17 topics;
- Assessment by Heaney's (1986) literature review and discussions with experts—52 topics;
- WPCF assessment by CH2M HILL's (1990) literature review and workshop—17 topics;
- Assessment by WERF and Bay Area Stormwater Management Agencies—25 topics;
- Assessment by WERF workshop's 60 delegates—28 topics;
- US EPA assessment (Field et al., 1997a)—77 topics; and
- Engineering Foundation Conference recommendations—27 topics.

Table 2–8. Research Needs in Urban Stormwater Quality— Composite List Cross-Referenced to the Individual Research Needs Assessments

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
	Sources and Monitoring								
1	Atmospheric deposition				4		6		2
2	Industrial sites						15		1
3	Thermal pollution						13		1
4	Use of dense rain gages and radar to describe storm patterns	11	3						2
5	Watershed response during winter conditions			9					1
6	Rainfall-runoff relationships for micro- storm management						9		1
7	Automotive sources						1	2	2
8	Construction sources						2		1
9	Litter sources						3		1
10	Build-up/wash-off processes in urban areas	1					5		2
11	Influence of land use on water quality		7			1.12			2
12	Fecal sources-use better indicators				9	1.2	11		3
13	Toxics sources and monitoring				17	3.1		12	3
14	Pesticide sources				25				1
15	Determine decomposition rate for various PAHs			3					1
16	Turbidity studies, settleability, particle sizes, etc.				18				1
17	Isotope tracking techniques for characterizing the nature of WWFs						14		1
18	Cross media issues				15				1
19	Flow meters to measure widely variable flows		5						1
20	Flow-weighted sampling devices for variable flows		6		19	1.3	12		4
21	Standards for sampling, analysis, and reporting for urban runoff pollutants	5							1
22	Cradle to grave tracking of urban water pathways and controls							17	1
23	Quality of roof runoff							10	1
	Receiving Water Impacts								
24	Behavior of urban runoff in mixing zones of rivers, lake, & estuaries	3	33			1.4			3
25	Feasibility of identifying "natural conditions" at the watershed scale			11					1
26	Impact of snowmelt on receiving water quality			6					1
27	Bioassay proc. for long-term exposures to heavy metal accum. in benthos	2	30	4					3
28	Fate of nitrogen inputs					1.11			1
29	Criteria for wet-weather quality standards	8	32						2
30	Mass balance of urban runoff and receiving water fluxes		31	5					2
31	Bioassay procedures for short-term intermittent exposures		29						1
32	Water quality response in water column & sediment	12							1
33	WWF physical stressors					1.5			1
34	Effect of urbanization on stream geomorphology						35		1
35	Indices to determine specific impacts of constituents e.g., BOD, metals				6		37		2
36	Small stream impacts					1.7			1
37	Sediment impacts & control					2.16			1
38	Large river impacts					1.8			1
39	Source water protection					2.4			1
40	Understanding regional differences in receiving waters			8	20				2
41	Stormwater-groundwater interactions	10				2.6			2
42	Vadose zone impacts					2.8			1

Table 2–8, cont. Research Needs in Urban Stormwater Quality— Composite List Cross-Referenced to the Individual Research Needs Assessments

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
43	Human health risk/ecosystem impact trade-offs						36		1
44	Groundwater pollution from highways							9	1
45	Evaluation of health risks					1.9		· 7	2
	Management								
46	Add solids handling to simulation models		35	14					2
47	Develop user friendly integrated decision support systems		42	15					2
48	Linkage of surface and subsurface phenomena		2						1
49	Interface simulation and optimization models		36			2.3			2
50	Analyze existing NURP, USGS, NPDES, and other data		38	16					2
51	Probabilistic performance criteria for wet weather control								
52	Integrate GIS to refine spatial analysis capabilities		4						1
53	Develop risk management methodologies	13				3.5		11	3
54	Combine available databases into a single database		39						1
55	Develop an integrated DSS for overall watershed evaluations						30		1
56	Watershed Ecosystem Model					2.14		16	2
57	Create and maintain an urban stormwater information repository					2.15			1
58	Develop more robust parameter estimation methods		34	13					2
59	Develop a watershed assessment methodology							19	1
60	Case studies of integrated stormwater management	16							1
61	Add real-time control to all aspects of urban stormwater models					4.17	25	3	3
62	Establish a network of urban research catchments			12				25	2
63	Watershed-based water quality standards			10					1
64	Methods for estimating the prob. distributions of dry and wet-weather flows		43	17					2
65	Riparian forest management					4.9			1
66	Criteria for model calibration/verification	14							1
67	Calibration of transport models using improved databases		14						1
68	Decision support systems with real-time control and all aspects of urban water							5	1
	Regulatory Policies and Financial Aspects								
69	Preparing effective and implementable NPS regulations				11				1
70	Areas where EPA can provide regulatory flexibility to achieve watershed goals.						27		1
71	Methods to allocate the costs of multi-purpose water projects		40						1
72	Cost/performance function data for stormwater controls	7			24		28		3
73	Quantify benefits of stormwater quality control		28					8	2
74	Contingent valuation to estimate the benefits of stormwater projects		41						1
75	How to develop sustainable watershed management programs								
76	CSO measures of success					4.10			1
77	Feedback on public involvement, participation techniques						31		1
78	How to translate public desires into action?				21		32		2
79	Stormwater management in new urban areas								
80	Feasibility of decentralized urban water management and privatization							26	1
81	Common elements of successes and failures.						33		1
82	Retrospective assessments of existing environmentally friendly developments				14				1
83	Environmental justice in management programs				23				1
84	Recognition of regional differences in appropriate management strategies				1				1

Table 2-8, cont. Research Needs in Urban Stormwater Quality—Composite List Cross-Referenced to the Individual Research Needs Assessments

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
85	Mechanism for coordinating storm water research across agencies			7					1
86	Improve EPA use attainability methodologies								
87	Environmental ethics to reduce litter							13	1
	Controls								
88	Effectiveness of swales		9						1
89	Reuse of urban runoff as cooling water		21						1
90	Modifying urban surfaces to reduce hydraulic and pollutant loads						10		1
91	Urban drainage design improvements for micro-storms						7		1
92	Demand management for automobiles							22	1
93	Toxics sources reductions								
94	Improved methods of source reduction								
95	Stormwater reuse					2.5			1
96	Swales instead of curbs					2.6			1
97	Storm inlet device					4.12			1
98	Industrial runoff control					4.3			1
99	Roadway/airport deicing					4.5			1
100	Instrumentation & monitoring to evaluate sewer hydraulics		10						1
101	Laboratory & field studies of deposition & scour in sewers	4	12						2
102	Use of simulation models in storm sewer design		13						1
103	Aquatic & non aquatic vegetative management				22				1
104	Cost-effective ways to rehabilitate & replace old sewers		11			5.3			2
105	Sanitary sewer system design practices					5.4			1
106	Sewer maintenance effectiveness					5.2	20		2
107	Sewer and tank sediment. flushing					4.36	23		2
108	Innovative design of sanitary and storm sewers							23	1
109	Short and long-term performance of porous and permeable pavments							21	1
110	Sludge/solids disposal aspects of control options		24						1
111	Design of storage/release systems to maximize pollutant control		17				24		2
112	Evaluation of groundwater injection systems		18						1
113	Treatment of heavy metals in urban runoff		23						1
114	Improved knowledge of O&M costs	9		2	5				3
115	Laboratory studies of high-rate treatment systems		15						1
116	Process control systems to optimize performance of control options	15	25						2
117	Effectiveness of disinfection with highly variable flows		16						1
118	Application rates for land disposal of urban runoff		20						1
119	Engineering considerations in using wetland systems								
120	Control of suspended solids						18		1
121	Integrated systems for flood and pollution control including reuse						19		1
122	Dissolved solids removal						21		1
123	Disinfection/pathogen detection					1.1			1
124	Continuous deflective system for litter control					4.14	17		2
125	Storage facilities design manual					4.16			1
126	CSO vortex controls					4.18			1
127	Cross flow plate settlers					4.27			1

Table 2–8, cont. Research Needs in Urban Stormwater Quality— Composite List Cross-Referenced to the Individual Research Needs Assessments

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
128	Runoff control using compost					4.8			1
129	Cross connection identification					4.15			1
130	High-rate sedimentation					4.19			1
131	Magnetic separation					4.20			1
132	Retrofitting DWF control facilities to increase stormwater control					4.22			1
133	CSO concepts for SSO's					4.23			1
134	SSO corrective action					4.24			1
135	Vortex/disinfection treatment demonstration project					4.26			1
136	High-rate disinfection					4.28			1
137	Demonstration of biofilters for high-rate treatment at DWF plants					4.29			1
138	High-rate ozonation pilot project in New York, NY					4.30			1
139	Triple purpose storage for I/I, CSO, and DWF					4.31			1
140	Storage/wetlands treatment demo. in Onondaga County, NY					4.33			1
141	Constructed vegetated treatment cells					4.34			1
142	ETV pilot for WWF controls					4.35			1
143	BMP design/effectiveness	6			10	4.6	16	20	5
144	Vegetative management practices				13				1
145	Long-term effectiveness of infiltration systems							6	1
146	Biofilm processes and biofiltration							18	1
147	Performance of WWF controls in cold climates							24	1
148	Impact of WWFs on wastewater treatment facilities	17							1
149	Endpoints of toxicants in detention ponds							1	1
150	Integrate landscape architecture into overall stormwater management systems							4	1
151	Reduce directly connected impervious area								0
152	Reduce I/I in house service laterals								0
153	Improved I/I control in sanitary and storm sewers								0
154	Sewer maintenance optimization								0

The number of topics for these seven research needs assessments totals 243. The net total of topics is smaller in that there is substantial overlap. To give an overview, all of these topics have been compiled in Table 2–8. The net total of 154 separate topics is listed under the following categories:

- Sources and Monitoring—23 topics;
- Receiving Water Impacts—22 topics;
- Management—23 topics;
- Regulatory Policies and Financial Aspects—19 topics; and
- Controls—67 topics.

2.4 Methods for Assessing Research Needs

Research needs can be assessed in a variety of ways. In a 1985 assessment of research needs in urban stormwater pollution sponsored by US EPA, Heaney (1986) relied on a thorough literature review. He culled research needs recommendations from various papers and reports and synthesized them into one comprehensive set. Torno's (1986) compilation of research needs represents the opinions of national and international experts obtained in open discussions as part of an urban stormwater conference. The 1990 WPCF/RF assessment of research needs in nonpoint pollution used a combination of literature review, expert panels, and user input in a one-day meeting (CH2M HILL, 1990). The 1996 US EPA research needs assessment used a combination of internal and external experts to develop the statements of unresolved problems and research needs.

The research needs assessment can be viewed as a portfolio selection problem wherein the objective is to maximize the present value of the expected net benefits from research activities. Research, by its very nature, is a risky investment. Thus, organizations make their best estimates of the potential payoff of various research investments and the probability of success of these research investments. The general objective is to select a mix of projects such that we have a high probability of a successful portfolio just as investors use in selecting among stocks, bonds, and other investment opportunities. While formal research planning models have been used for large research programs, such as the Department of Defense which is funding thousands of projects at any given time, most research funding organizations rely on less formal approaches.

2.5 Purposes of Urban Stormwater Research Program

Viewing research funding as a portfolio selection problem, the most fundamental question is: Exactly what is the purpose(s) of the program? Of course, this varies depending on the investor and his or her objectives, e.g. short-term high-risk, high-return investments or conservative long-term investments for retirement. Most investors select a mix of investments to ensure that the portfolio will achieve their goals.

Unlike traditional financial investments, research investments in the short-term are viewed as low risk, and conversely, long-term are viewed as higher risk. Wet weather research has many different clients. WERF is supported by organizations that would be expected to prefer applied research with well-defined tasks and a fairly high probability of success as measured by immediate value to the user community. These applied research projects are typically smaller, last a relatively short time (1 to 2 years), and are awarded based on responses to a formal request for proposals (RFP). These projects are open to a wide variety of groups including consultants and universities. At present, this model dominates research funding in the United States and Europe. The limitation of funding only short-term, low-risk applied research projects is that they tend to be less innovative since the problem, and often the solution, is prescribed in the RFP. These projects are also of limited value in supporting the training of graduate students in the wet weather area. US EPA is the primary source of wet weather research support in the United States. These funds come from various groups within US EPA and range from highly applied studies to more fundamental research. In the 1970s, the US EPA Wet Weather Research Program was more centralized and had a larger budget. Sponsored projects were a blend of fundamental and applied research and technology transfer. These projects supported many graduate students, many of whom are now leading professionals in the field.

The demise of this research program, along with companion urban water research programs in other federal agencies in the early 1980s, caused the U.S. WWF research community to dismantle and move into other areas where research support was available, e.g., hazardous waste. At present, only a handful of university faculty members have maintained an interest in WWF research and very few graduate students receive training in this area.

At the opposite end of the spectrum from highly applied, solicited research is basic research characterized by unsolicited proposals from universities and other research organizations wherein the proposer presents ideas and requests support for longer-term, basic research whose immediate utility may be unclear. Local utilities and agencies have difficulty supporting such activities. Even a federal agency, such as US EPA, may have trouble justifying such longer-term investments. The National Science Foundation (NSF) supports this kind of research, but until recently, their urban stormwater–related funding has been very small. A recent NSF/EPA/USDA cooperative initiative on watersheds offers hope of better support in this area.

Given a low level of current funding of WWF research in the United States, what mix of projects is appropriate? A popular tendency is to put all available resources into applied research with the hope of short-term payoffs and "success stories" that can be used to request higher levels of future support. As support levels increase, then some of the funding can be used to support longer-term, more fundamental research with increased support for graduate students. This approach did not work well for the water research community during the 1980s when funds were tight and researchers attempted to be more relevant. The result was continuously diminishing resources.

A possible new dimension for WWF research lies in international cooperation. The cost of supporting essential, long-term experimental research is high and requires a funding agency's multi-year commitment. For example, porous and permeable pavement is an important area of WWF research. Long-term experimental laboratory and field studies are essential to evaluate the efficacy of this approach, but at present, only a few such studies are being done in the world. International cooperation would make it possible to support these efforts with input from the international user community. The recent emergence of the European Union as a major funder of research in Europe offers real possibilities for establishing internationally funded projects in key WWF areas.

More detailed descriptions of WWF research needs are presented in the next five chapters.

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CHAPTER 3.0

SOURCE CHARACTERIZATION

3.1 The Problem

Characterization of runoff pollutants is essential to understand impacts on receiving waters, to develop control strategies, to operate collection systems and treatment works, and to predict the ultimate fate of pollutants in the environment. Runoff is a common pathway for pollutants that originate in non-aquatic systems to enter aquatic systems. For example, results of Forster's (1996a, b) study of runoff from metal roofs in Germany show high metal concentrations in roof runoff. If this roofing material were replaced by a benign material, then the source would be eliminated along with the need for expensive controls to convert the metals into another form, e.g., sludge beds. Boller (1997) demonstrates that urban runoff control measures merely transfer metals from one destination to another. The fate and transport of metals were demonstrated in three scenarios: through a combined sewer, through a separate storm sewer, and through decentralized infiltration. In the combined sewer, the majority of the copper in urban runoff becomes bound with the sludge from the WWTP. In separate storm sewers, a large portion of the metals enters the receiving waters and becomes trapped in the benthic ecosystem. If on-site control measures are used, (e.g. decentralized infiltration), metals accumulate in the pervious ground. Thus, long-term control of metals (and all conservative pollutants) is accomplished by eliminating the source. The relative mass loads of copper from Boller's (1997) scenario analysis are shown in Figure 3–1.

The cases presented by Boller (1997) and Forster (1996a, b) highlight the need for pollutant source characterization to identify sources of contamination, and to design integrated means of eliminating them or eliminating their exposure to precipitation and runoff.

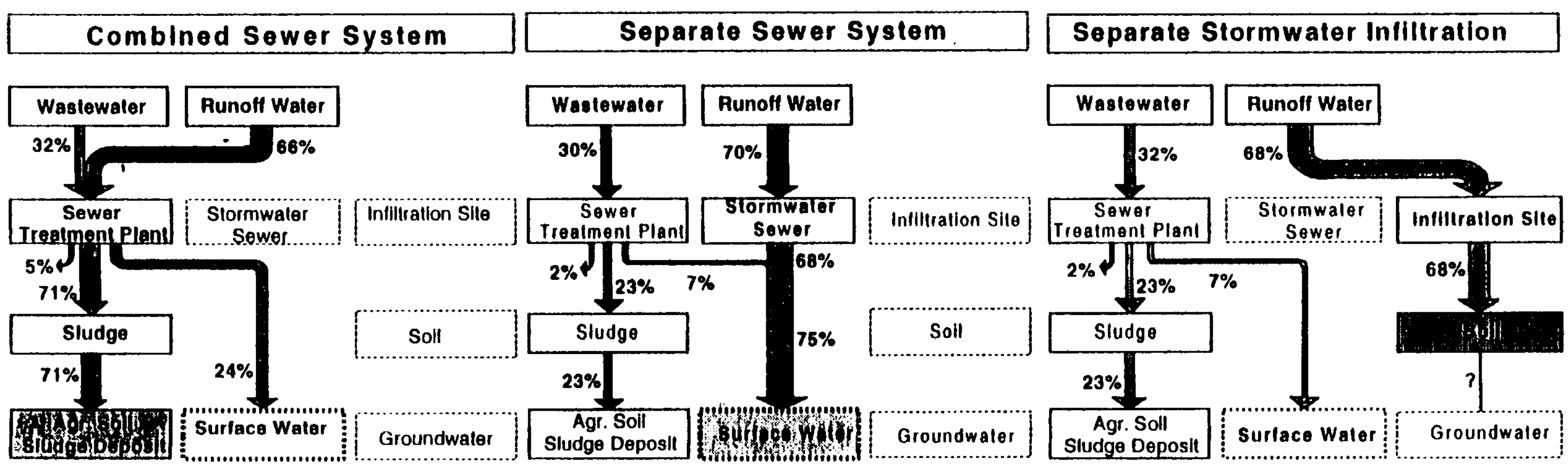

Figure 3–1. Relative Mass Flow of Copper in Different Urban Drainage Systems (Boller, 1997)

WERF

Aside from metals, urban runoff pollution consists of solids, nutrients, thermal effects, and toxic substances. The sources of these pollutants tend to be diffuse in nature; even when discharges occur at individual points (e.g., separate storm or combined sewer outfall), the source of the pollution tends to be dispersed over the urban land surface (Nix, 1994). Moreover, pollutants are only part of the problem; impervious surfaces found in the urban landscape increase runoff volume considerably, adding a physical hydraulic impact on the receiving waters.

Deposition of particles on land surfaces occurs naturally as part of atmospheric–lithospheric interaction. Atmospheric particulates are derived from natural processes (e.g. wind erosion), or from anthropogenic sources such as fossil fuel exhaust. This research area is primarily concerned with anthropogenic sources of pollution and their impact on urban runoff quality. Ball, Jenks, and Auborg (1996) stress the importance of wind in pollutant accumulation rates. Atmospheric depositional processes have been an active area of research; however, atmospheric scientists and water quality researchers have interacted relatively little.

Contaminant loading produced by wet weather flows has been studied extensively (Zison, 1980; US EPA, 1983; Hargesheimer, Lewis, and Seidner, 1986; Barr Engineering Company, 1987; Choi and Park, 1988; Birtwell et al., 1988; Driver and Tasker, 1988; Bartel and Maristany, 1989; Desbordes and Hemain, 1990). A reasonably high level of knowledge about source emissions has accumulated because of work of national scope (e.g., US EPA, 1983; Driver and Tasker, 1990; Driscoll, Shelly, and Strecker, 1990), as well as many regional and local studies to characterize urban runoff sources. In general, contaminant concentrations increase below discharge locations, but little is known about how they accumulate on the watershed and how they enter the runoff.

Heaney et al. (1998a) assess recent literature regarding overall impacts of the automobile on urban runoff. The automobile has caused urban sprawl in the United States over the past 50 years (Heaney et al., 1998a, b). The proliferation of the automobile has led to land-use changes and has directly contributed pollutants, making the automobile a major contributor to urban runoff pollution. The hydrologic effect of impervious surfaces is well known. A large fraction of impervious surfaces in the United States has been created to accommodate automotive transportation. These surfaces create near ideal wash-off conditions for accumulated pollutants. Research should track the total pollutant load that results from automobile transportation to aid in developing innovative control measures and, perhaps, lead to actual source reductions.

Contaminant loading has also been related to sedimentation conditions (Zison, 1980). The most common impact associated with sediment is the accumulation of large and heavy particulates near and downstream of runoff discharge locations and a corresponding increase in contaminant concentration in these "hot spots." Floatable solids, typically vegetative debris, partially decomposes and sinks to form organic mud deposits. An important mechanism of sediment contamination is the precipitation of soluble materials upon change of pH, oxidation reduction potential (ORP), or temperature. Rubin (1976) stated that when solutions of trace metals, or other dilute solutes, come in contact with solid phases, the concentration of the constituent in the solute usually decreases. It may take polluted solids a long time to pass through a contaminated stream. The transport of pollutants are, therefore, difficult to relate to specific runoff events. Much of the suspended contaminants during wet weather events may be resuspended sediment that had been deposited during previous storms (Wilber and Hunter, 1980).

Organization of research needs in this section follows the logic of characterizing urban land surface depositional processes and pollutants associated with urban land use, characterization of physical transport processes, and finally monitoring needs associated with source characterization. This typology is useful because the processes are the focus of research, and detailed sub-topics of importance are viewed in light of the overall physical processes associated with them.

Table 2–8 identifies 23 research needs topics as pertinent to source characterization. While differing in some details, many have common research elements. For this section, three overall topics were selected to cover source characterization needs. Ten topics listed in Table 2–8 relate to the characterization of pollutants having to do with urban land use. Six topics generally fit the category of fate and transport characterization, and seven have to do with monitoring issues related to source characterization. Not every research need identified in Table 2–8 is specifically referenced in the following sections (3.1 through 3.3), although all areas identified in Table 3–1 share common elements. Needs not specifically mentioned in Sections 3.1 to 3.3 may not be less critical, but were less represented in the literature. The literature base in the area of source characterization is not as broad as in other areas; nevertheless, this topic is equally important.

Research resources should be allocated to source characterization within the context of broad-based urban water-management goals. Characterization of pollutant sources is essential in understanding the fate and transport pathways through the urban hydrologic cycle. Knowledge of these pathways is essential to develop control and management schemes. The US EPA has designated a research team to investigate the life-cycle impacts of materials. The Systems Analysis Branch of the Sustainable Technology Division, under the National Risk Management Research Laboratory, conducts studies such as "Cleaner products through life-cycle design" and "Enhanced methods for life-cycle and total cost assessments." Researchers of urban runoff-quality projects, especially those involving source characterization, should cooperate with researchers working from the total systems viewpoint. Thus, research funded in this area should be performed in the context of overall systems improvement.

Table 3–1. Research Needs for Characterization of Sources (Unprioritized)

Section	*Table 2–8 ID #*	*Research Topic*
3.0 Source Characterization		
3.2 Urban Land Surfaces & Land Use	1	Atmospheric deposition
	2	Industrial sites
	3	Thermal pollution
	7	Automotive sources
	8	Construction sources
	9	Litter sources
	11	Influence of land use on water quality
	13	Toxics sources
	23	Quality of roof runoff
	14	Pesticide sources
3.3 Fate & Transport Processes	5	Watershed response during winter conditions
	6	Rainfall-runoff relationships for micro- storm management
	10	Build-up/wash-off processes in urban areas
	22	Cradle to grave tracking of urban water pathways and controls
	15	Determine decomposition rate for various PAHs
	17	Isotope tracing techniques for characterizing WWFs
3.4 Monitoring	12	Fecal sources, use better indicators
	16	Turbidity studies, settleability, particle sizes, etc.
	4	Use of dense rain gages and radar to describe storm patterns
	18	Cross media issues
	19	Flow meters to measure widely variable flows
	20	Flow-weighted sampling devices for variable flows
	21	Standards for sampling, analysis, and reporting for urban runoff pollutants

3.1.1 References

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3.2 Characterization of Pollutants Associated with Urban Land Use

Pollutants on urban land surfaces may be dispersed over a wide area by means of atmospheric mixing and localized processes on urban land surfaces (e.g., residential impervious surfaces such as roof tops and road surfaces contributing pollutants directly from their construction material). Shepp (1996) estimates that runoff concentrations of petroleum hydrocarbons from automotive-intensive land uses typically range from 0.7 to 6.6 mg/L. Revitt et al. (1996) identified the sources of hydrocarbons in urban runoff through an extensive monitoring program. Recent studies of the quality of road runoff include Sakai, Sumiyama, and Tanaka (1996), Wada, Miura, and Muraoka (1996), and Ball, Jenks, and Auborg (1996). These studies help to understand the relationship between road use and pollutant generation. Roof runoff is generally considered to be "clean water" that may be usable for other on-site purposes such as lawn watering and toilet flushing. Cisterns have been used for many centuries to capture roof runoff for subsequent use. Recent studies in Japan confirm that roof runoff is of good quality for toilet flushing and landscaping (Sakakibara 1996). However, Forster's (1996) studies in Germany indicate high copper and zinc concentrations from metal flashings used on the roofs. Boller (1997) also reports high metal concentrations in urban runoff, which may accumulate in soils if infiltration-based BMPs are encouraged. Runoff pollution from industrial land uses differs from that of other diffuse pollution, in that it is derived from more localized activities. This may ease abatement measures somewhat; however, the toxicity of the pollution may be greater than from other urban land uses. Runoff from 10 industrial sites in North Carolina were evaluated for a broad list of conventional plus metal and organic toxicants (Line et al., 1996). Metal concentrations were highest from automobile salvage yard runoff, whereas wood-preserving sites had the highest chromium concentrations.

3.2.1 Research Needs

Two research areas concern the characterization of pollutants associated with urban land uses. Identification of pollutant sources associated with urban land uses is critical to improving source control. Also, knowledge of the physical processes occurring on the urban land surface is important to improving control measures and improving current models of pollutant accumulation and wash-off. In this area, rates of accumulation and entrainment into runoff are especially important in improving current models.

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3.3 Physical Transport and Wash-Off Processes

The research area, physical transport and wash-off processes, concerns the physical processes that transport various pollutants from urban land surfaces. Pollutants deposited from the atmosphere or from previous runoff events are suspended in the runoff flow-stream. Transport from the land surface to the receiving water via runoff includes several runoff events or various depositional and resuspension transitions during one event. The processes include transport in storm sewer conduits; and pollutants may react physically, chemically, or biologically during transport. Nowakowska-Blaszczyk and Zakrzewski (1996) studied concentration changes of several pollutants through the urban water cycle in Poland. Comparing concentrations in rain water, runoff from roofing materials, parking lots, city streets, and drainage system conduits, the researchers found that pollutants were introduced into runoff from urban surfaces and storm drainage networks. Resuspension of deposits in pipes, as well as from roofs, demonstrated the wash-off process (Nowakowska-Blaszczyk and Zakrzewski, 1996). Sansalone and Buchberger (1996), Montrejaud-Vignoles, Roger, and Herremas (1996), and Parente and Hulley (1994) studied runoff quality from roadways and found significant increases in solids and COD. However, relationship between storm characteristics and pollutant concentrations was found to be slight, highlighting the lack of process-level knowledge regarding wash-off. Isotope tracing techniques show promise in tracking pollutants through the various runoff transport processes. Isotope tracing techniques use stable isotopes to determine the possible sources. Stable isotopes do not decay, and therefore may be used to trace the origin of the sample. Doll (1997) reports a research program on the Neuse River in North Carolina to trace the origin of nitrogen in the river. In this research, the ratio of ^{15}N to ^{14}N is measured and compared against the atmospheric ratio. This research is still in progress and results are not available, but, it is expected that sources of nitrogen, such as livestock runoff, can be identified. This information will then be used to calibrate a nutrient runoff model.

3.3.1 Research Needs

Research needs related to wash-off and transport processes are important for developing control and management schemes, and for long-term basin modeling analyses. Research should integrate sediment transport studies (Section 7.2.2) and innovative control needs with physical entrainment and wash-off phenomena. Doll (1997) shows that stable isotope tracing is promising for \identification of pollutant sources and how they are transported through urban areas. The focus of wash-off characterization should be the identification of sources by understanding pollutant pathways, and the characteristics of wash-off that may aid in the understanding of control measures.

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3.4 Monitoring

Monitoring is composed of three main questions: how to monitor? what to monitor? and where to monitor? Work continues to develop more cost-effective sampling devices, e.g., Dowling and Mar's (1996) culvert composite sampler for obtaining flow-weighted wet weather samples. Fuchs et al. (1996) describe the use of biofilm samplers to indicate heavy metal variations in an urban area. The spatial and temporal variability in rainfall remains an important issue for wet weather management and monitoring. Mikkelsen, Arngjerg-Nielsen, and Harremoes (1996) have established a nationwide rain gauge network in Denmark for monitoring short and intense rain events. The U.S. NEXRAD radar system should prove useful for estimating point rainfalls in urban environments (Seliga and Chen, 1996). Philadelphia has modernized its rain gauge network to improve its database for operating the WWTP during wet weather periods (Day and Nicolo, 1996). Legg, Bannerman, and Panuska (1996) used a rainfall simulator to determine the rainfall-runoff relationship for 20 residential lawns in Madison, Wisconsin. The runoff coefficients for newer lawns were significantly greater than for older lawns. The effect of antecedent soil moisture on infiltration was unclear. Snowmelt may also be an important runoff-based transport mechanism. Based on 7 years of measurements in Norway, Thorolfsson and Brandt (1996) found the volume of snowmelt runoff to be much greater than typically considered in drainage designs, resulting in much more flooding and CSOs in winter than in summer. Measurements in Alaska of snow and snowmelt runoff (Saxton, Siftar, and Fowler, 1996) show that snow is, in general, more contaminated than snowmelt runoff.

3.4.1 Research Needs

Spatial and temporal variability of precipitation accounts for much of the uncertainty in hydrologic analysis. Therefore rainfall data should cover larger areas for longer times. A primary research need in water quality monitoring is the standardization of information (Urbonas, 1994; Strecker, 1994). Measurement techniques that characterize solids must be improved. Capturing a representative solids sample from runoff remains difficult, and settling velocity tests are widely variable and expensive. Efforts should be devoted to these fundamental areas of monitoring.

3.4.2 References

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CHAPTER 4.0

RECEIVING WATER IMPACTS

This chapter covers surface and subsurface receiving water impacts. The research topics identified in Table 2–8 were organized into the outline as shown in Table 4-1. The grouping was necessary because some topics overlap, and others are not emphasized in the literature. Eight topics were combined in subsection 4.1.1; two each in subsections 4.1.2, 4.1.3, 4.1.4, and 4.3.1; and three each in subsections 4.1.5 and 4.2.1.

4.1 General Topics

The goals of controlling urban runoff remain elusive (Heaney and Huber, 1984; Heaney, 1988). Broadening the view of receiving water impacts to incorporate stream geomorphology has progressed significantly. This broader view has been helpful in designing effective urban stream restoration programs. During the past five years, the use of more formalized risk analysis methods to evaluate receiving water impacts has been much discussed (Heaney, 1995; Heaney, Wright, and Samsuhadi, 1996).

Because of its disperse nature, its complex impacts, and its difficult control in an urban setting, urban wet weather flows have attracted the attention of a diverse group of researchers over the past several years. Studies of the impacts on receiving waters have called for an increased understanding of biology and chemistry, transport mechanisms, BMP efficiencies, and regulatory effectiveness. To cost-effectively implement wet weather flow control measures, these disciplines must be integrated, from both a regulatory and a technical standpoint (Andoh, 1994). The National Pollutant Discharge Elimination System has not been effective across the board, and many industries have not met permit obligations (Hoag and Rossmiller, 1994), although many successful applications of innovative wet weather flow quality control technology have been used. Studies of the interactions between BMP installation and receiving water impact have addressed vegetative covers, impervious surfaces, sediment mechanics, storage and recycling devices, riparian strips, habitat, and land uses

(Startin and Lansdown, 1994; Argue, 1994; Fujita, 1994). Maxted and Shaver (1997) suggest that more data on the effectiveness of BMPs must be developed, particularly in going beyond the traditional evaluation of physical treatment characteristics to evaluating the effectiveness of biotic habitat protection. In their limited study, they found that at a high level of development, BMPs did not appear to be effective in protecting biologic diversity downstream; they suggest studying different levels of impervious cover, and different regions. Field et al. (1994) find that non-storm loadings from wet weather flow systems in urban areas are critical and must be addressed if substantial improvements are to be made in receiving water quality.

It is important to separate impact from effect. Impact is really a concept, often defined in the context of a regulatory or analysis framework that includes economic, social, and political considerations as well as scientific and technical issues. Effects can be defined as measurable changes from background or reference conditions. In the analysis of physical, chemical, and biological effects, it is appropriate to emphasize biological measures, which integrate receiving system physics and chemistry into a more general measure such as biological or ecological health, integrity, or quality. Furthermore, an emphasis on effect analysis assists in translating existing information from a descriptive, subjective assessment and qualitative analysis to an objective assessment and quantitative analysis of defined effects.

Land development physically alters the watershed. The magnitude of changes varies with the proportion of developed watersheds. Typical impacts of development, including urbanization, are modification of stream channels, increased erosion and sedimentation in the stream, modified hydrographs, and altered riparian vegetation which change the stream temperature regime. Urbanization of a watershed also changes the release and delivery of chemicals naturally produced in the watershed, resulting in an increase in macro- and micronutrients for some time after disturbance (Vitousek, 1977). After development, the stream usually receives a mix of chemical contaminants produced by human activities. The most severe modifications involve complete containment of stream channels and wholesale modification of all headwaters streams and small tributaries. Under less extreme conditions, the stream course may be modified to accommodate development or the stream may be channelized to provide for flood control purposes. Where natural channels remain in urbanized areas there are usually several reaches where the stream channel is constrained or efforts made to reduce erosion or channel movement by using revetments or rip-rap.

Table 4–1. Research Topics on Receiving Water Impacts (Unprioritized)

Section	*Table 2–8 ID#*	*Research Topic*
4.1.2 Rivers, Lakes, Estuaries & Wetlands	24	Behavior of urban runoff in mixing zones of rivers, lakes, and estuaries
	25	Feasibility of identifying "natural conditions" at the watershed scale
	26	Impact of snowmelt on receiving water quality
	29	Criteria for wet weather quality standards
	33	WWF physical stressors
	35	Indices to determine specific impacts of constituents, e.g., BOD, metals
	38	Large river impacts
	40	Understanding regional differences in receiving waters
4.1.3 Nutrient, Metals, & Toxicant Cycling	28	Fate of nitrogen inputs
	30	Mass balance of urban runoff and receiving water fluxes
4.1.4 Biomonitoring	27	Bioassay procedures for long-term exposures to heavy metal accumulation in benthos
	31	Bioassay procedures for short-term intermittent exposures
4.1.5 Benthic& Sediment Effects	32	Water quality response in water column & sediment
	37	Sediment impacts & control
4.1.6 Land Use & Urbanization	34	Effect of urbanization on stream geomorphology
	36	Small stream impacts
	39	Source water protection
4.2.1 Wet Weather–Groundwater–Vadose Zone Impacts	41	Wet weather-groundwater interactions
	44	Groundwater pollution from highways
	42	Vadose zone impacts
4.3.1 Ecosystem Risk & Human Health Risks	43	Human health risk/ecosystem impact trade-offs
	45	Evaluation of health risks

The impacts of wet weather discharges on aquatic biota have been well documented. Davies (1991) and McHardy, George, and Salanki (1985) have examined the impacts of heavy metals on aquatic organisms. Cook et al. (1983) and Benke et al. (1981) studied stream ecosystems in Georgia, and Pratt, Coler, and Godfrey (1981) compared benthic population trends along urban and nonurban areas of the Green River in Massachusetts. General findings included change in benthic community dynamics with the amount of urbanization and identification of urban runoff as the cause of community disruption. Although these studies point to wet weather discharges as an impact agent, few studies have examined direct cause and effect relationships of urban runoff for receiving water aquatic organisms (Heaney and Huber, 1984). Further, the general conclusion of the extensive work on urbanized and unurbanized streams in Washington State streams was that hydrologic changes (including the associated sediment release) were more important factors than chemical contaminants in determining overall stream health (Pedersen, 1981; Richey, 1982; Bissonnette, 1985) and fish populations (Scott, 1982; Steward, 1983). These hydrologic changes are particularly important in small streams down-gradient from hilly terrain undergoing significant increases in impervious surface because of development (Roesner, 1997a,b). According to Roesner, the effect of urbanization on these watersheds can result in a 6- to 12-fold increase in peak flow rate, with concurrent adverse changes in erosion, flooding, and water quality characteristics downstream. Figure 4-1 summarizes the multifaceted impacts of urban runoff on wetland receiving waters.

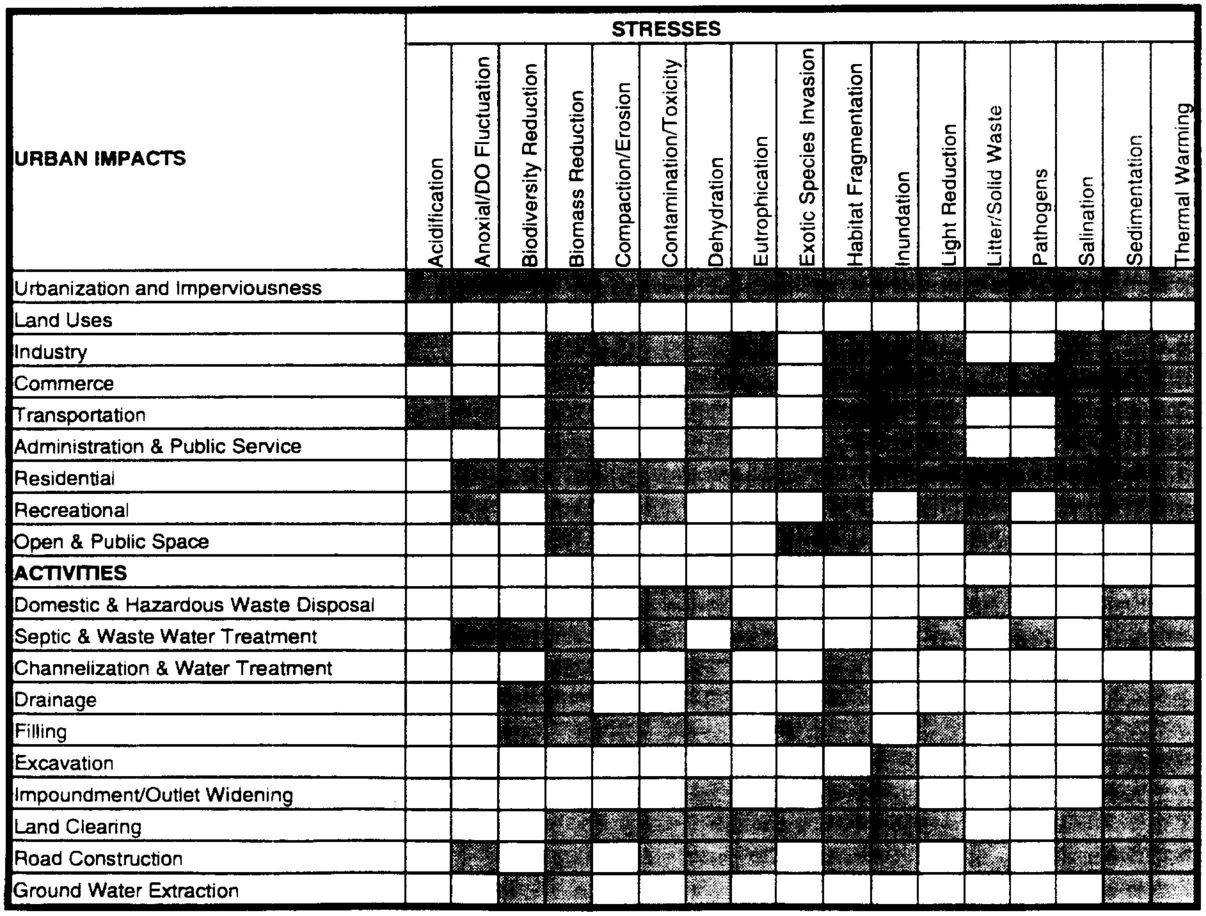

Figure 4–1. Impacts and Stresses on Wetlands Caused by Urbanization (Hicks and Larson, 1996)

Recent state-of-the art reviews include INTERURBA, a 1991 Engineering Foundation conference that addressed receiving system impact (Herricks, 1995) and a 1996 Engineering Foundation conference that addressed receiving water impacts (Roesner, 1997b).

Pitt et al. (1997) list the following categories of receiving water impacts:

- Sedimentation damage in stormwater conveyance systems and in receiving waters.
- Nuisance algae growths from nutrient discharges into quiescent waters.
- Inedible fish and undrinkable water caused by toxic pollutant discharges.
- Shifts to less sensitive aquatic organisms caused by contaminated sediments and destroyed habitat.
- Property damage from increased drainage system failures.
- Swimming beach closures from pathogenic microorganisms.
- Water quality violations, especially for bacteria.

The Center for Watershed Protection used 26 wet weather flow indicators to assess receiving water conditions (Claytor 1996; Claytor and Brown 1996). These 26 indicators were aggregated into six categories: water quality, physical/hydrological, biological, social, programmatic, and site.

US EPA's latest national water quality inventory (*Water Environment & Technology*, 1996) indicated only a slight improvement in the attainment of beneficial uses in the nation's waters. Agricultural runoff was the most important source of contaminated waters entering the nation's rivers and streams, while urban runoff ranked fourth. The latest US EPA National Water Quality Inventory indicated that problems in lakes were mostly caused by agricultural runoff, while urban runoff ranked third (*Water Environment and Technology*, 1996). These sources resulted in bacteriological growth, siltation, and excess nutrients. The latest US EPA National Water Quality Inventory indicated that urban runoff was the leading source of problems in estuaries, mainly as excess nutrients and bacteria (*Water Environment and Technology*, 1996). Continuing research on receiving waters should focus on the fundamental issue of the definition of a receiving water, and how to measure the impacts. The inclusion of groundwater and understanding the linkages between surface and subsurface waters is an important research need. Understanding interactions between the water column and the sediment bed in a stream, river, or lake is an important unresolved issue; the focus should be on what management techniques minimize sediment transport where this has been impacted by urbanization. The impact of urbanization and its increasing imperviousness on stream form and the practical management of these effects is an important question to be explored. Human health and ecosystem health studies should continue including the comparative risk field to better evaluate the significance of these risks. Lastly, impacts to the human economic system should also be explored.

4.1.1 References

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4.1.2 Rivers, Lakes, Estuaries, and Wetlands

Hicks and Larson (1996) found a connection between wetland degradation and the increase of impervious surface from urbanization, and that at about 10% to 20% imperviousness, rapid degradation of wetlands occurs. The authors suggest that the "ecological integrity of wetlands is affected by the amount of impervious surface in the watershed, and that aquatic macroinvertebrate communities do serve as indicators of wetland condition." Heidtke and Tauriananen (1996) describe an aesthetic quality index for the Rouge River. Rauch and Harremoes (1996) contend that the primary indicators of acute urban water pollution are oxygen and ammonia. The authors conducted continuous simulations with a simplified deterministic model and determined that intermittent discharges from the sewer system or the wastewater treatment plant cause acute water pollution. Wada, Miura, and Muraoka (1996) explore the relationships between chemical oxygen demand (COD) and suspended solids (SS) and several hydrologic factors and found that the amount of the last rainfall and the inter-event time influence the concentrations of COD and SS. Shorter inter-event times decrease concentrations of pollutants, possibly because of build-up and wash off. Increases in highway traffic volume, particularly trucks and buses, and the relative emissions from each, also tend to increase concentrations. Yoder and Rankin (1997) describe indices and the biosurvey program developed for the state of Ohio. Livingston (1997) develops an interesting paradox. The author describes the innovative watershed-based pollution control and water management programs initiated in the state of Florida, but then focuses on the continuing degradation of the rapidly growing Tampa Bay area by urban stormwater runoff. The author argues that the complex sources of pollution in the Tampa Bay area require a more holistic approach to solve them, rather than a programmatic or disciplinary one.

4.1.2.1 Research Needs

Improved techniques are needed to assess urban runoff impacts. These would include modeling or analysis of the fate of pollutants or contaminants, considering the episodic nature of urban runoff and the time-related changes that integrate both the physical characteristics of the runoff and receiving system, and the chemical characteristics associated with multiple events and differential receiving storage and transport. Assessment procedures that monitor ecosystem conditions and accurately measure the ecosystem state are also needed. The development of a regulatory structure more appropriate to the episodic nature of urban runoff and to identify indices and indicators specific to urban runoff is also a significant research need.

4.1.2.2 References

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4.1.3 Nutrient, Metals, and Toxicant Cycling

By means of an extensive literature review, Herrmann and Klaus (1996) trace pathways of water, nitrogen, and phosphorus in the urban hydrologic cycle and developed a budget for each constituent. The authors contend that sustainable systems involve the minimization of waste and the re-use of nutrients. This requires understanding of the entire life cycle of the nutrient within the urban hydrologic cycle. Novotny and Olem (1994) and Chapra (1996) extensively review toxicant conceptual and mathematical models. Chapra (1990) developed a conceptual model of toxicant loading budget for lakes. Decay and diffusive sediment feedback were ignored, however, sorption, volatilization, and sediment resuspension were included; this results in a conservative estimate of the net loss rate. Compounds were mapped in three zones based upon their sorption and volatilization characteristics. The water zone includes substances that sorb weakly and are soluble, and have low removal rates because sedimentation and volatilization are not significant. The air zone includes weak sorbers that are relatively insoluble, but are removed rapidly due to volatilization. The sediment zone includes compounds that sorb strongly and are subject to resuspension. Using a budget approach, Pettersen, Naef, and Broman (1997) determined the concentrations and flux of 12 petroleum aromatic hydrocarbons in settling particulate matter adjacent to a refinery on the Baltic Sea in Sweden. Concentrations and fluxes did not differ significantly from background levels, so either the refinery is an insignificant contributor of PAH loading, or the hydraulic residence time is low. Nizeyimana et al. (1996) used GIS and population data from the U.S. Census Bureau to develop nitrogen loadings to Pennsylvania surface streams from septic systems, developing a nitrogen budget model of these watersheds.

4.1.3.1 Research Needs

Insufficient information is available regarding the cycle of nutrients, metals, and toxicants through the urban hydrologic system. More work must be done similar to that of Herrmann and Klaus (1996) in tracing these pathways. Possible models of the cycle can be used as source management and control tools.

4.1.3.2 References

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4.1.4 Biomonitoring and Bioassessments

Barbour (1997) advocates the use of bioassessments because they reflect cumulative impacts that might not be detected otherwise. The author summarizes state-by-state development of bioassessment approaches and the subsequent regional perspective that lends itself to watershed management. Herricks et al. (1997) assessed short-term exposure test systems, and found that, to be adequate, they must meet the following requirements:

- Fast response time with a time scale for the response matching the time scale for the exposure.
- Capacity to respond to changing conditions (e.g., track changing toxicity).
- Response to the effects of a single stressor, as well as integration of the impact of multiple physical, chemical, and biological stressors.

Peterson et al. (1996) argue that the lack of adequate toxicity testing for photosynthetic organisms inhibits regulation of toxics such as pesticides and heavy metals because they are relatively nonbiodegradable. The authors found that toxicity for plants may be several orders of magnitude more sensitive than the typical aquatic invertebrates tested. They argue that the inclusion of site-specific toxicity conditions and ecologically relevant organisms is needed to achieve the most appropriate testing at minimal cost. Maltby et al. (1995) conducted toxicity tests on stream water and roadway discharge water contaminated with hydrocarbons, carbon, and zinc on the amphipod *Gammarus pulex*. Significant short-term toxicity was found. An example of a long term in situ study of the response of an organism to urban runoff can be found in Crukilton et al. (1997). The authors describe short- and long-term toxicity testing of several macroinvertebrate species, including *Ceriodaphnia dubia* and *Pimephales promelas*. Crukilton et al. (1997) found that short-term (24 to 48 hour) adverse impacts were typically not noticed within the macroinvertebrate community, but longer term impacts (7 to 10 days) were. Nyholm (1996) discusses the interaction of biodegradable toxins with nutrients and the synergistic effect of toxics. The author suggests that "degradable toxicity is the toxicity of the fresh effluent less its persistent toxicity."

4.1.4.1 Research Needs

The development and acceptance of testing procedures is needed to effectively analyze the impact of both urban runoff and receiving systems on toxic response for single events, multiple events, and over time scales appropriate to changing watershed conditions.

4.1.4.2 References

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4.1.5 Benthic and Sediment Impacts

Brick and Moore (1996) conducted hourly samplings of trace metals in an oxic, alkaline river with high levels of metals stored in bed sediments. Results indicate that most major elements and ions and alkalinity show no diurnal variation; however, particulate metal concentrations show substantial increases resulting from increases in suspended material at night. Scoullos, Dassenakis, and Zeri (1996) studied the Louros estuary in Greece, which has a very narrow mixing zone and, particularly in summer, exhibits a pronounced saline water wedge on the bottom. The authors found that particulate metals desorbed from riverine sediments and remained within the saline wedge, which acts as a sink. Spliethoff and Hemond (1996) reconstruct history with sediment core samples of the Aberjona River, north of Boston, finding direct correlations between concentrations of heavy metals and depth as key industries arrived in the watershed and left the area. Skipworth, Tait, and Saul (1996) describe a bench scale test to simulate the erosion process of solid deposits in sewers in the United Kingdom. The authors found that the erosion rate depended upon the initial rate of change of flow rate and the final flow rate during the experiment, and not on any steady state variable. Morrisey, Roper, and Williamson (1997) contend that the premise that urban stormwater outfalls cause observed chronic toxicity in fauna living in sediments to be mainly circumstantial. The authors conducted a detailed biological and chemical analysis of iron, lead, and zinc in sediment samples and found that sediment texture and the concentration of lead were main factors in influencing the faunal amounts; with pH and iron concentrations in pore water causing an effect in some cases. Di Toro et al. (1991) developed a model of sediment oxygen demand (SOD) of the anaerobic zone of sediments of freshwater lakes and streams. The model includes the flux of methane and ammonia from the sediment to the water above, and the methane and nitrogen gas fluxes in bubbles from the sediment to the surface.

4.1.5.1 Research Needs

More research is needed in identifying interactions between the sediment and receiving waters, both in sewers and in receiving waters. Effort should be concentrated on sediment impacts in the water column.

4.1.5.2 References

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4.1.6 Land Use, Urbanization, and Geomorphology

Ferguson (1997) tracks alluvial stream response to urbanization in the Piedmont area of Georgia. According to the author, the process of urbanization can be separated into the following cycles: clearing and cultivation, then reclearing and urbanization. Examples of stream aggradation, incision, and possible reconstruction are given. Ferguson found that urbanization reduces the low flows in a stream, and in times of rain, makes the intensity and frequency of the peaks higher;

which is the worst of all hydrologic regimes, particularly for wildlife dependent upon stable stream hydrology. The effect on the stream is to increase the erosive power, and to "remold the entire riparian corridor in a brown flurry of erosion, sediment, and habitat loss." MacCrae (1997) found that, in an urban stream in Ontario, a channel adjusting to urbanization increased almost three times its original cross-sectional area because of the increased peak flow, and boundary shear stress along the streambank. The author argues that mitigation should also include a no net change of the transverse component of shear stress along the channel perimeter based upon an index method developed by the author. Sovern and Washington (1997) argue that returning to "natural" hydrologic conditions is impractical and cost prohibitive. These authors suggest that a "new urban stream" can be constructed by stabilizing the streambed, confining aquatic habitat microchannels, revegetating channel banks, reducing sediment discharge in the watershed (reduce channel width), and vegetating the channel bed. Case study examples are given. Harris, Saunders, and Lewis (1997) suggest that urban rivers in the arid west tend to be much more flashy than their counterparts in the east, and urbanization only increases this trend. The impact of man's activities (such as water diversions for agriculture) have a much more direct link to water quality in western streams. Less vegetation implies less buffering from solar radiation and temperature swings. Schueler and Claytor (1997) explore the potential of using the amount of impervious cover within a watershed as an index of stream health. This was based upon correlations between impervious cover and factors affecting stream quality such as "stream temperature, fish diversity, instream habitat, macroinvertebrate diversity, nutrient loading, channel stability, changes in stormwater flow peaks and frequency, spawning success, and bacterial contamination."

4.1.6.1 Research Needs

The ongoing development and evaluation of techniques to integrate urban runoff analysis in overall watershed management, particularly the impacts of urbanization on watersheds, is needed.

4.1.6.2 References

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4.2 Groundwater and Vadose Zone

4.2.1 Stormwater–Groundwater–Vadose Zone Impacts

Pitt et al. (1996) summarize the potential contributions of urbanization to groundwater pollution. Groundwater flow may be reduced by urbanization; however, the remaining flow that percolates tends to be contaminated stormwater runoff. The authors describe the various urban wet weather flow pollutants, such as pathogenic microorganisms, toxicants, nutrients, pesticides, organic compounds, heavy metals, inorganic compounds, and salts and various treatment techniques for them. The authors advocate the use of stormwater infiltration to make up for the lack of recharge due to impervious surface buildup from urbanization. However, they caution that it should be restricted to less polluted areas, such as residential areas, and that the groundwater should be monitored. Mikkelsen et al. (1996a) and Mikkelsen, Jacobsen, and Boller (1996b) found that heavy metals and PAHs present little groundwater contamination threat, if surface infiltration systems are used. However, the more mobile pesticides and salts can be a problem. Squillace et al. (1996) and Zogorski et al. (1996) describe the potential of wet weather flow as a source of groundwater methyl tert-butyl ether (MTBE) contamination. Mull (1996) examines the connection between leaky sewers and surficial aquifers, which, particularly in industrial sites, can cause significant contamination of groundwater. Mull found significant increases in chemical oxygen demand (COD), ammonium, nitrate, chlorinated hydrocarbons, and pathogenic bacteria. Traffic areas are the third most important source of groundwater contamination in Germany (after abandoned industrial sites and leaky sewers). Trauth and Xanthopoulos (1996) developed a pilot groundwater monitoring network in Karlsruhe, Germany, finding oxygen depletion and increases in calcium, sulfate, hexazinone, potassium, boron, ethylene diaminetetraacetic acid (EDTA), and trichlorethene with urbanization. They found that the relative concentration of these pollutants increased by about 30 to 40% over 20 years. Gremillion et al. (1995) used isotope tracing methods in several central Florida watersheds and determined that rivers received about 75% of their flow from the surficial aquifer. This phenomenon may be caused by to the unique Florida limestone stratigraphy, however, the possibility of a tight coupling between surface and groundwaters in some regions is a research need to be explored.

4.2.1.1 Research Needs

See Section 5.2.1.5, Linking Surface and Subsurface Phenomena.

4.2.1.2 References

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4.3 Human Health

4.3.1 Human Health Risks and Ecosystem Impact Trade-offs

O'Shea and Field (1993) summarize wet weather flow quality and its relationship to potential for human disease, tracking pathogenic microorganisms from their sources such as driveways, roof runoff, sidewalks, paved parking areas, and paved roadways. The authors investigate receptor pathways such as agricultural use and recreational use, including bathing, and suggest that there is a significant potential for diseases to occur. Typical indicators such as *Escherichia coli* are not very useful. The authors also investigate disinfection technologies for wet weather runoff. They conclude that, due to the relatively high risk involved, if US EPA's policy continues to emphasize re-use of stormwater, disinfection requirements and bacteriological criteria must be reevaluated. Swimmers in front of wet weather flow outfalls at Santa Monica Bay, California, were 50% more likely to develop a variety of symptoms than those who swam 400 m from the same outfall (*Water Environment and Technology*, 1996). Human fecal waste was present in the stormwater collection systems. Eggleston, Keith, and DePasquale (1996) describe closures of the

Boston area's Tenean Beach because the limit for fecal coliform or enterococcus had been exceeded. Rempel et al. (1996) summarize the work of assessment of CSO impacts to the Red River near Winnipeg, Manitoba. The focus of their effort was coliform bacteria, and minimizing the public health risk, as the Red River is used extensively for recreational purposes. Reynolds, Gerba, and Pepper (1995) found human enteric viruses (a class of viruses associated with sewage pollution) adjacent to marine outfalls. Lack of an inexpensive and reliable testing method prevents these viruses from being routinely monitored in the United States. The authors compared traditional cell culture methods with direct reverse transcriptase-polymerase chain reaction amplification and successfully detected several enteric viruses, including polio virus.

4.3.1.1 Research Needs

Effective risk assessment and management techniques for urban runoff to assure protection of human health and provide a means of balancing human and ecological considerations is needed. A particular need is a better indicator of the relative harm wet weather flows pose to human health because of combined sewer overflows. Current indicator methods cannot sufficiently distinguish between harmful impacts and the possible presence of contaminants.

4.3.1.2 References

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CHAPTER 5.0

MANAGEMENT

This chapter focuses on management tools of the urban wet weather flow management professional. Significant advances have been made in this area, particularly in terms of computer modeling and links between models and spatial and geographical databases. These areas are covered, as well as organizational structure, decision support systems, and watershed management linkages. The research topics covered in this chapter are outlined in Table 5–1. The more significant research needs identified in Table 2–8 are covered with single-page summaries of current work. Some areas were combined when research literature on the topic was not available. Some topics were added to fully cover the broader subject matter involved.

5.1 Organizational Structure

Jones, Clary, and Brown (1998) describe existing models of stormwater management institutions, such as watershed-based committees and institutions, stormwater utilities, local agencies, and private utilities. For each stormwater management institution, the authors identify its integration, flexibility, efficiency, effectiveness, and responsiveness. According to Jones, Clary, and Brown (1998) the key issues future institutions will have to address are: financing, staffing, administrative authority, clear regulations and standards, legal challenges, regional solutions, risk management, maintenance, monitoring and evaluation, non-structural source control strategies, retrofitting, technology transfer, practice guidance, and public involvement. A particular need is evaluation of the effectiveness of different models of management institutions.

5.1.1 Reference

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5.2 Models and Decision Support Systems

The goal of this section is to briefly review the existing models used in urban stormwater management, including noting critical deficiencies and strengths, then to evaluate technological advances in geographic information systems (GIS), decision support systems (DSS), real-time control, and artificial intelligence techniques and how they might assist in modeling urban stormwater. Following this overview, analyses of micro subjects within this field are presented. Much of this overview is from Heaney et al. (1998).

Within the United States, users continue to rely on existing urban stormwater models. Commonly used models are listed in Table 5–2 (Huber, 1997). TenBroek and Brink (1996) compared several continuous stormwater simulation models including STORM and SWMM. Donigian, Huber, and Barnwell (1996) compared the attributes of six urban and seven non-urban wet weather flow models. Mercer, Cave, and Kaunelis (1996) summarized the use of a variety of stormwater and receiving water models—including SWMM, WASP, the Watershed Management Model, and P8—as part of the Rouge Project in the Detroit area. Donahue, Breen, and Kublak (1996) summarized the use of modeling and evaluation tools to select a cost-effective CSO control plan within a watershed perspective. Shoemaker et al. (1996) compare the attributes of six stormwater models. Swarner and Thompson (1996) present the results of extensive measurements and modeling of SSO problems in Seattle, Washington. The results of an extensive SSO evaluation using XP SWMM for the Miami sewer system are described by Walch et al. (1996). Kachalsky and DeSantis (1996) describe modeling and evaluation methods for optimizing CSO control in New York City. Herrmann and Klaus (1996) developed general water and nutrient budgets for urban water systems which included stormwater.

A variety of international urban stormwater models have been released in recent years. Neylon et al. (1996) describe the first version of the HydroWorks stormwater quality management model being developed by Wallingford Software in the United Kingdom. Foller, Frentzel-Beyme, and Wittenberg (1996) show how MOUSE can be used to optimize a combined sewer system in East Germany. Dempsey, Eadon, and Morris (1996) describe SIMPOL, a simplified urban pollution modeling tool developed as part of the U.K. Urban Pollution Management Research Program. SIMPOL models the stormwater system as series of tanks. Bente and Schilling (1996) propose an object-oriented approach for an urban hydrologic simulation system. Davies (1996) discusses the importance of the appropriate blend of modeling and data for SSO evaluations including the advantages and disadvantages of SWMM and HydroWorks. An extensive evaluation of the Sydney, Australia, SSO problem was done with MOUSENAM and SEEKER to simulate and optimize control options (Hayes, 1996). Ji, Vitasovic, and Zhou (1996) describe a fast model for evaluating the hydraulics of sewers and open channels. This work shows the implicit solution scheme in the SUPERLINK model to be much faster than EXTRAN's explicit solution. Gent, Crabtree, and Ashley (1996) surveyed models that can simulate solids deposition and resuspension in sewers. They describe MOUSETRAP and HydroWorks QM that supersede WALLRUS and MOSQITO. Jack, Petrie, and Ashley (1996) describe several models for characterizing sewer sediments. They briefly describe the WALLRUS/HydroWorks PM hydraulics model, the STOAT wastewater treatment performance model, and the MOSQITO, HydroWorks-DM, and MOUSETRAP sewer flow water quality models. Imbe, Ohta, and Takano (1996) used a water budget to establish the impact of urbanization on the hydrologic cycle of a new development near Tokyo, Japan. This development focuses on reduction of hydrologic impacts by encouraging infiltration systems and storing rainwater. Mitchell, Mein, and McMahon (1996) describe a water budget approach to integrated water management in Australia. Budgeting is done at the individual parcel, neighborhood, and wider catchment scale. A current gap in urban stormwater modeling is the inability to properly incorporate the impact of rainfall on frozen surfaces in urban areas. Thorolfsson and Brandt (1996) describe a Norwegian experience in which "worst case" conditions occur during winter. They recommend development of new mathematical models to handle this special case.

Real-time control (RTC) systems will be an integral part of future urban stormwater decision support systems. Schilling (1996) summarizes the state of the practice regarding the use of RTC including applications around the world. Nelen and Broks (1996) summarize use of RTC in eight Netherlands cities. Lavellee, Marcoux, and Bonin (1996) report 30% to 60% reduction in the volume and frequency of CSOs in Quebec City using RTC. Rauch and Harremoes (1996a, b) describe an RTC system that includes optimization using genetic algorithms. Schmitt (1996) evaluates improvements in two German CS systems from using RTC. Volume reductions were 30% in one case and 9% in the other. Sirkin (1996) cautions that RTC should only be used after determining some necessary, preliminary information for the stormwater system. Kjaer, Wilson, and Mark (1996) describe using MOUSE ONLINE, an extension of the Danish Hydraulic Institutes's MOUSE model, for RTC.

Table 5–1. Research Topics on Urban Wet Weather Flow Management (Unprioritized)

Outline Topic	*Table 2–8 ID#*	*Research Topic*
5.1 Organizational Structure		
5.2 Models and Decision Support Systems	66	Criteria for model calibration/verification
5.2.2 Enhancements in Existing Models		
5.2.2.1 GUI/Object Oriented Programming		
5.2.2.2 Improvements in the Analysis of Rainfall Input Data		
5.2.2.3 Improved Parameter Estimation Techniques	58	Develop more robust parameter estimation methods
5.2.2.4 Data Centered Approaches to Enhancing Stormwater Modeling	50	Analyze existing NURP, USGS, NPDES, and other data
	54	Combine available databases into a single database
5.2.2.4.1 Real Time Control	61	Add real-time control to all aspects of SWMM
5.2.2.4.2 Stochastic Simulation	64	Methods for estimating the probability distributions of dry and wet weather flows
	51	Probabilistic performance criteria for wet weather controls
5.2.2.4.3 Neural Networks		
5.2.2.4.4 Calibration of Transport Models Using Improved Databases	67	Calibration of transport models using improved databases
5.2.2.5 Linking Surface/Subsurface Phenomena	48	Linkage of surface and subsurface phenomena
5.2.2.6 Linking with Atmospheric Models		
5.2.2.7 Solids Handling Capability/Sewer System Modeling	46	Add solids handling to simulation models
5.2.3 Development of Integrated Decision Support Systems	47	Develop user friendly integrated decision support systems
	55	Develop integrated decision support systems for overall watershed evaluations
	68	Decision support systems with real-time control and all aspects of urban water
5.2.2.1 Integrate GIS to Refine Spatial Analysis Capabilities	52	Integrate GIS to refine spatial analysis capabilities
5.2.2.2 Interface Simulation and Optimization Models	49	Interface simulation and optimization models
5.2.2.3 Development of Integrated DSS for Overall Watershed	56	Watershed ecosystem model
5.2.2.3.1 Watershed Models		
5.2.2.3.2 Ecosystem Models	65	Riparian forest management
5.2.2.4 Develop Risk Management Methodologies	53	Develop risk management methodologies
5.3 Watershed Management Linkages		
5.3.1 Watershed Assessment Methodology	59	Develop a watershed assessment methodology
	60	Case studies of integrated stormwater management
5.3.2 Development of Long-Term Watershed Case Studies		
5.3.3 Urban Research Catchment Network	57	Create and maintain an urban wet weather flow information repository
	62	Establish a network of urban research catchments
5.3.4 Development of Watershed-Based Water Quality Standards	63	Watershed-based water quality standards

MacArthur et al. (1996) describe a computer-based system for conjunctive operation of the WWTP and stormwater controls in Monroe County in upstate New York, which includes the city of Rochester. Cantrell et al. (1996) summarize an application of HydroWorks developed specifically to use with an existing RTC system in Lima, Ohio, an early RTC application in the United States. Miles, Moore, and Tarker (1996) describe methods and models for evaluating I/I problems associated with SSOs.

Models and decision support systems are incorporating GIS. US EPA recently released a package called BASINS, which includes a CD for each of the EPA regions (US EPA, 1996), BASINS links nonpoint models including HSPF and QUAL2E using ArcView. An AWRA conference proceedings contains several useful articles on evaluating urban wet weather flow management problems with GIS (Hallam et al., 1996). Shamsi and Fletcher (1996) describe how ArcView can be used for a variety of GIS-related links to urban wet weather flow models and data management including AM/FM systems. Haubner and Joeres (1996) describe using GIS as a preprocessor for the Source Loading and Management Model (SLAMM) to estimate pollutant loads in urban areas, including a case study of Plymouth, Minnesota.

Although the model is important, much of the focus has shifted to the related needs of database management, developing GISs, and a sophisticated user-friendly interface, all combined in a package called a decision support systems (DSS). These necessary components of a DSS are described in Figure 5–1 (Dunn et al., 1996). Reitsma (1996) defines DSSs as ".. computer-based systems which integrate state information, dynamic or process information and plan evaluation tools into a single software implementation." A DSS is a system that assists in bridging the gap between data and models to solve difficult partially undefined problems. Most of the current work in DSS in the water field has been in the simulation of complex reservoir operations, because of the financial impact of hydropower. A thorough description of this area can be found in Jamieson and Fedra (1996a, b) and Fedra and Jamieson (1996). This series of articles describes the conceptual design, planning capability, and example application of the Water Ware DSS, a complex river basin DSS that combines a "GIS, a geo-referenced database, groundwater flow, surface water flow, hydrologic processes, demand forecasting, and water-resources planning." Dunn et al. (1996) describe the hydrologic processes used within the DSS. The DSS mimics the hydrologic system in terms of its organization, as can be seen in Figure 5–2.

Table 5–2. A Variety of Urban Hydrologic, Hydraulic, and Water Quality Models (Huber, 1997)

Model	Agency/Source	Primarily Hydrology/ Hydraulics	Continuous Simulation or Storm Event	Complete Dynamic Flow Routing?	Quality Simulation?	Graphical User Interface
DR3M-QUAL[a]	USGS	Hydrol	CS/SE	No	Yes	ANNIE[a,c]
HEC-1[b]	HEC/Vendors	Hydrol	SE	No	No	3rd party
HEC-2[b]	HEC/Vendors	Hydraul (backwater)	Steady state	No	No	3rd party
HSPF[a,c]	EPA	Hydrol	CS/SE	No	Yes	ANNIE[a,c], 3rd party
Hydroworks[d]	HR Wallingford in UK, Montgom. Watson in US	Hydrol/Hydraul	CS/SE	Yes	Yes	Yes
ILLUDAS, ILLUDRAIN	Ill. St. Water Survey	Hydrol	SE	No	Yes, with Auto/QI	No
MIKE 11[e]	Danish Hydraul. Inst.	Hydraul (open chan.)	SE	Yes	Yes	Yes
MOUSE[e]	Danish Hydraul. Inst.	Hydrol/Hydraul	CS/SE	Yes	Yes	Yes
P8[f]	Wm. W. Walker, Jr.	Hydrol	CS/SE	No	Yes	Menu
Santa Barbara	Vendors	Hydrol	SE	No	No	3rd party
SCS	NRCS/Vendors	Hydrol	SE	No	No	3rd party
STORM[b]	HEC/Vendors	Hydrol	CS	No	Yes	No
SWMM[c,g]	EPA/OSU	Hydrol/Hydraul	CS/SE	Yes	Yes	3rd party
UNET[b]	HEC/Vendors	Hydraul	SE	Yes	No	No

Web addresses for model. Unless otherwise specified, all with prefix: http://

a. h2o.usgs.gov/software/surface_water.html
b. www.wrc-hec.usace.army.mil/
c. ftp://ftp.epa.gov/epa_ceam/wwwhtml/ceamhome.html
d. www.hrwallingford.co.uk/
e. www.dhi.dk
f. www.shore.net/~wwwalker/
g. www.orst.edu/dept/ccee/swmm.htm

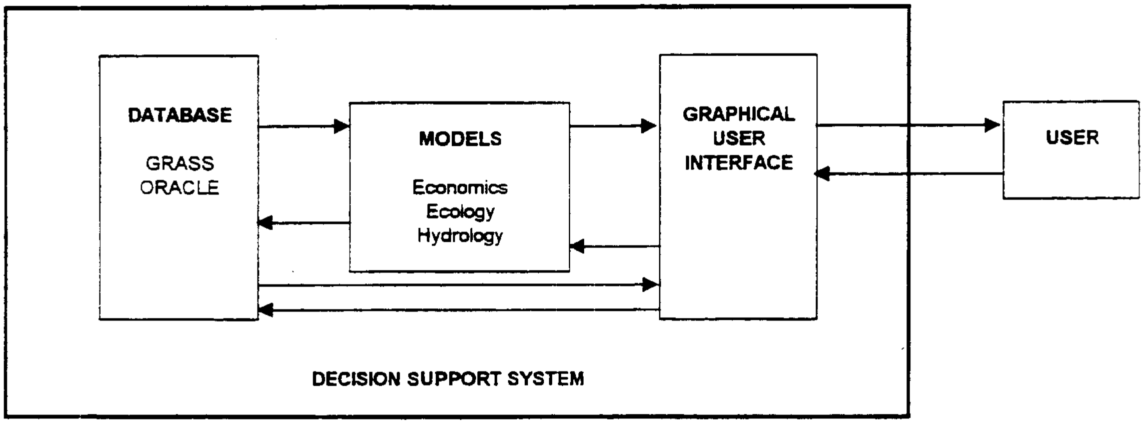

Figure 5–1. The Components of the NELUP DSS (Dunn et al., 1996)

DSSs are also used to enhance input of information. Griffin, Bauwens, and Ahmad (1994) describe an "intelligent assistant" which assists in training professionals in the interdisciplinary field of urban drainage modeling by providing definitions (in several languages), data on coefficients and parameters, and a graphical standard front end to several existing models. Illustrating the state of the art are an example of an input screen from this DSS (Figure 5–3) and an example of output from a DSS, viewed in conjunction with map information (Figure 5–4). A significant need is the application of this technology to the urban wet weather flow management field.

In summary, the area of models and DSS is evolving rapidly. Significant effort is still needed in developing graphical user interfaces (GUIs) and restructuring older model codes. This will enable them to be linked with other appropriate optimization and simulation software, GIS, DSS, and external databases. The complex, unstructured nature of the urban stormwater management problem makes it an interesting case for DSS. A particular subset of DSS for urban stormwater models is the issue of RTC. These systems are typically operated in a dynamic environment which uses real-time data in conjunction with optimization and simulation modules to maximize the volumes intercepted, and thence minimize the volume of CSO spills to the environment, in what is termed an integrated predictive control approach (Lavellee, Marcoux, and Bonin, 1996). Such systems' intensive use of data and the dynamic environment in which they operate demand DSS. An example of the organization of such an RTC/DSS system can be found in Figure 5–5.

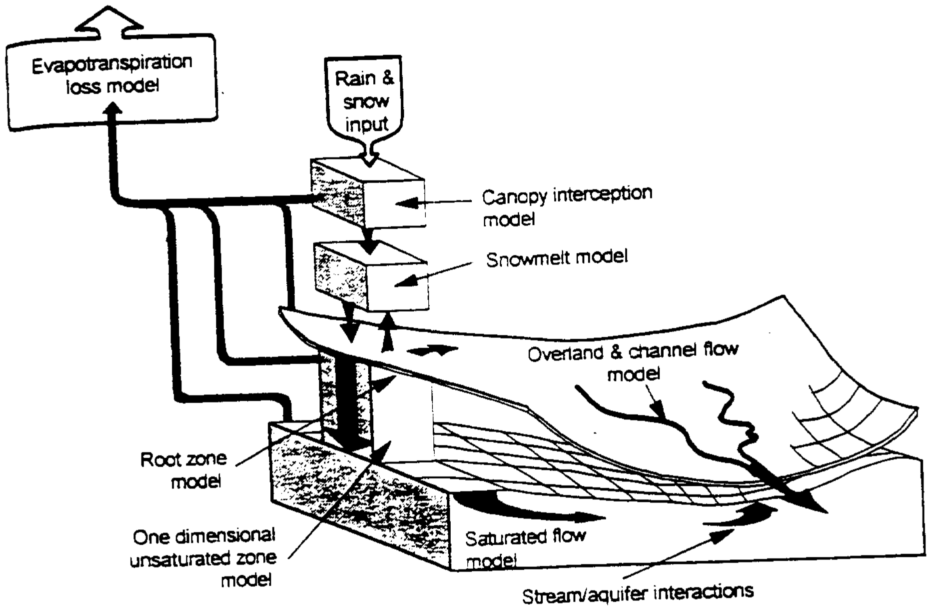

Figure 5–2. Schematic Diagram of SHETRAN Flow Model (Dunn et al., 1996)

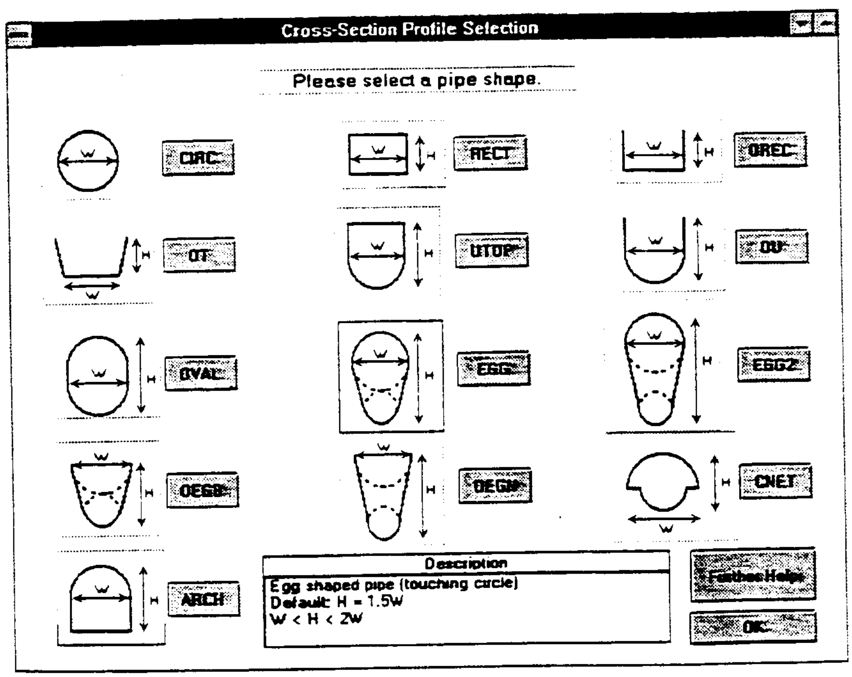

Figure 5–3. Creating an Input File, Selecting Cross-Section Profiles (Griffin, Bauwens, and Ahmad, 1994)

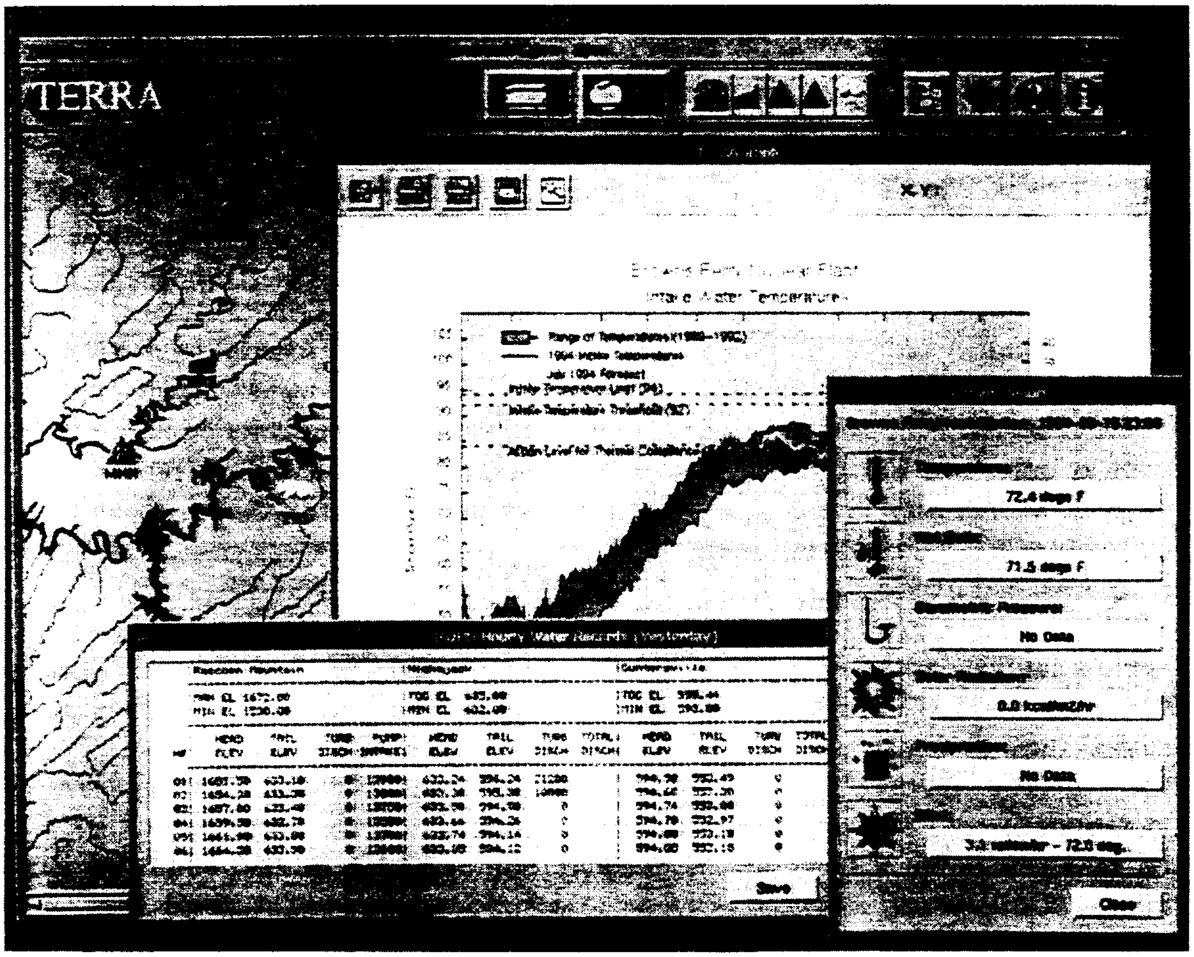

Figure 5–4. TVA Environment and River Resource Aid (TERRA) (Reitsma, 1996)

Lavellee, Marcoux, and Bonin (1996) summarize a feasibility study conducted before implementing the RTC system. The authors outline the major steps in the design strategy:

- Characterization of the existing network;
- Diagnosis of the existing CSO problem, usually through modeling and calibration;
- Design of a CSO control strategy (long-term plan); and
- Tests of the performance of the control strategy.

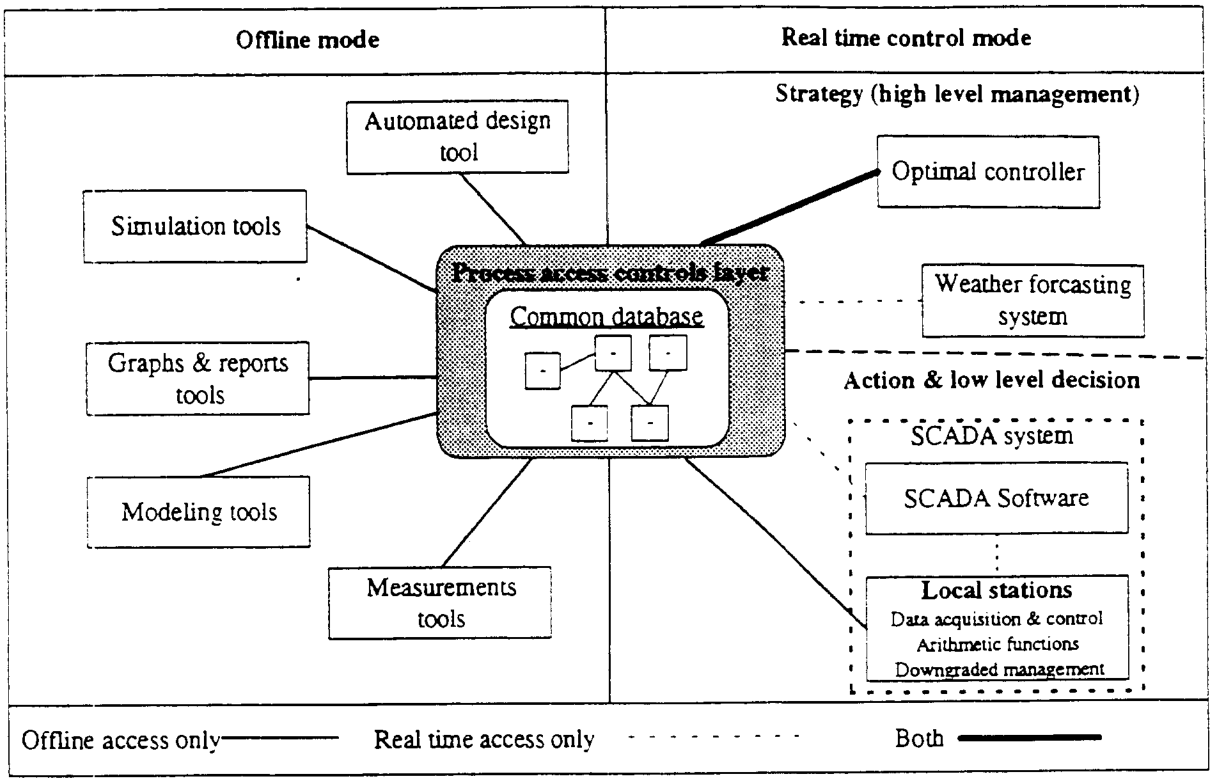

Figure 5–5. CSO Control Strategy Design Tools (Lavellee, Marcoux, and Bonin, 1996)

The authors describe the process and the design of the RTC system, including the configuration of local stations (sensors, flow regulators, data loggers, and communications devices), supervisory control and data acquisition system (SCADA), rainfall forecasting system, and optimal control system. The optimal control system must integrate the entire system and data inherent within each component. Integrating these data into optimized decision strategies that minimize CSOs requires decision-support tools. Several specific topics and research recommendations follow.

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5.2.2 Enhancements in Existing Models

5.2.2.1 Graphical User Interface/Object Oriented Programming

For an overview of the object paradigm and its effect on modeling and programming, see *Environment International* (1995). Bente and Schilling (1996) offer an object-oriented software concept for development of hydrologic models. The advantage of using this system is the standardization of structural components, so they can be individually replaced or enhanced, and new components easily added. This concept usually includes, by definition, a graphical user interface (GUI). Shamsi (1997) presents an overview of currently available GUIs for the SWMM model. The GUIs are compared based on common tasks associated with SWMM modeling and rated in tabular form. Huber (1997) compares many of these same GUIs along with the European models. Ahmed (1994) develops an object-oriented stormwater planning model to allow the evaluation of BMPs in new developments. Such a tool is desirable in development planning because it allows the user total flexibility in choosing an appropriate BMP, its size, locations, etc. Djokik and Maidment (1991) developed an object-oriented urban stormwater model within the Arc Info GIS system, using the rational method for hydrologic analysis. The model uses the network of storm sewers to route flows, and generated drainage basins based upon triangular irregular networks (TIN).

5.2.2.1.1 Research Needs

Huber (1995) emphasizes the need for parallel advances in the fundamental modeling engine, particularly in the areas of model conceptualization, numerical techniques, databases, and integration with ancillary software such as GIS. A possible combination of the two points is that object-oriented software development may allow better modeling abstract objects more closely mimicking the behavior of physical objects. However, the continuity of this development with previous SWMM work can only be maintained by an extensive code rewriting of the model engine which is a significant expense. An alternate method may be to restructure only parts of the code, particularly the user interface and input/output modules to enable linkage with other programs and develop GUIs as an interim measure.

5.2.2.1.2 References

Ahmed, F. (1994) *The Utility of an Object-Oriented Software Tool for Planning Management Practices for Urban Stormwater In Ontario.* Guelph, ON: The University of Guelph.

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5.2.2.2 Improvements in the Analysis of Rainfall Input Data

Analysis of rainfall input data is a common task prior to stormwater modeling. Selection of a design storm from the data has been controversial. Zhu and Schilling (1996) suggest that design storm methods have the advantage of compressing data, which becomes particularly important for large stormwater systems. Essentially, each system must be modeled to determine what level or frequency of event results in surcharges or flooding of the system. Another technique is filtering. Zhu and Schilling (1996) suggest that the practice of compressing rainfall data to small increments of about 1 to 60 minutes, common in stormwater modeling, leads to filtering errors, which can underestimate peak flows. The model amplifies this error when predicting overflow volumes. The authors developed a method for estimating this error.

A new technology attracting much research effort is the use of radar to supplement and give a better spatial definition of rainfall gages. Faures et al. (1995) determined that, in a small, 4.4-hectare semiarid catchment, the largest source of variability was spatial. The authors point out that modeling at this scale using a single rain gage will yield significant errors due to spatial variability. Radar rainfall techniques help overcome this disadvantage. Auchet and Faure (1996) provide an overview of a technique of calibrating radar rainfall data to measured rainfall. Einfalt, Gustafsson, and Lumley (1996) find significant differences between measured rainfall amounts and those predicted using radar rainfall data. Lumley et al. (1996) compare modeled flow predictions using radar rainfall data and measured rainfall data.

Cowpertwait et al. (1996) applied the Neyman–Scott rectangular pulses rainfall model to many sites throughout the United Kingdom; the model was then regionalized by regression analysis of input parameters. A disaggregation technique was performed on the hourly rainfall series to allow output on a five minute level. The authors determined that using the regional model for ungaged sites yielded reasonable results.

5.2.2.2.1 Research Needs

More work should be done on calibration and processing of radar rainfall techniques to supplement rain gages. Is it possible, for a given area, to determine the optimum number of gages necessary for calibration? Better integration of this research with traditional stochastic hydrology research should be done as well.

5.2.2.2.2 References

Auchet, P., and Faure, D. (1996) Radar measurement of rainfall in real time and objective control of the adjustment of rain gage data. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

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Lumley, D., Gustafsson, L. G., Einfalt, T., and Balmer, P. (1996) Comparison of radar and raingauge data for runoff modeling Part 2: Flow prediction results from the Goteborg catchment *Proceedings of the 7th International Conference on Urban Storm Drainage,* Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

Zhu, H-J., and Schilling, W. (1996) Simulation errors due to insufficient temporal rainfall resolution. *Atmos. Res.* **19–32** (42): 1–4.

5.2.2.3 Improved Parameter Estimation Techniques

Many parameters commonly used in hydraulic modeling are difficult to estimate or measure. Cowpertwait et al. (1996) developed a technique for reproducing statistical properties of hourly and daily rainfall series for different catchments in the United Kingdom with limited data. The reproduced series are created by analysis of regional models, probability analysis of available data, and regression analysis. Parameters commonly required by models can then be selected from the regional ranges based upon spatial criteria and professional judgement. Kenner et al. (1996) used a combination of models and geographic rainfall distributions to determine hydrologic coefficients with the least amount of error. Lee, Hoshi, and Masukura (1992) developed a set of dimensionless discrete runoff hydrographs for determining flow from a plane rectangular catchment. An advantage of this approach is that it is more suitable for use in urban watersheds, as the time scale varies with the intensity of runoff. King (1992) presents a literature review and database of methods for determining infiltration. The author found that many urban runoff models use empirical methods because researchers lack complete information necessary for physically based methods.

Kusuda and Arao (1996) determined the energy loss coefficients at drop structures (non-surcharged manholes), and Sakakibara, Tanaka, and Imaida (1996) developed energy loss coefficients for surcharged manholes. Aszetely and Lyngfelt (1996) modeled manholes in three dimensions with finite elements to also determine loss coefficients.

5.2.2.3.1 Research Needs

A possible approach is to incorporate parameter uncertainty, similar to first order error analysis, directly into new models. Then the models would give sensitivity ranges on the output. Another technique is to use genetic algorithms for assisting in calibration of models against known data, such as the study done by Liong, Chan, and ShreeRam (1995).

5.2.2.3.2 References

Asztely, M., and Lyngfelt, S. (1996) Three-dimensional numerical modeling of energy losses in a manhole. *Proceedings of the 7th International Conference on Urban Storm Drainage,* Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

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Liong, S. Y., Chan, W. T., and ShreeRam, J. (1995) Peak-flow forecasting with genetic algorithm and SWMM. *J. Hydraul. Eng.* **121** (8): 613–617.

Sakakibara, T., Tanaka, S., and Imaida, T. (1996) Energy loss at surcharged manholes-model experiment. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

5.2.2.4 Data Centered Approaches to Enhancing Stormwater Modeling

5.2.2.4.1 Real-Time Control

A good introduction to the concept of real-time control in stormwater modeling can be found in Norreys and Cluckie (1996). The authors point out the advantages of dynamic, physically based stormwater models versus empirically based models developed via linear control theory. Because of the need to recalibrate to changing conditions, at this time physically based models cannot adapt quickly to real-time data, particularly in large systems. Empirical models simplify the drainage network, and as the authors point out, do not simplify hydraulic behavior any more than the kinematic wave theory. However, the linear approximation is only good for a narrow operating range. The conditions of pumping, pressure flow, and backwater effects are beyond the capability of linear control-based models, so a physically based simulation tool must be used in these conditions. Norreys and Cluckie's approach is to model the system in trunks, in a hybrid approach. Results indicate very close agreement with existing calibrated models. Pleau, Tremblay, and Colas (1996) describe an integrated system using three tools: a database management tool, a control tool, and a utility tool. Within these tools is information on the sewer networks, simulation parameters, meteorological models, hydraulics and storage models, real-time performance modules, and optimization modules. According to Cantrell et al. (1996), the city of Lima, Ohio, "operates one of the most sophisticated real time control systems in the U.S." The system is unusual in that the model, Hydroworks, incorporates real-time control as one of its modules. Cantrell et al. (1996) conclude that the use of real-time control in conjunction with a hydraulics model allows much more rapid testing of prospective conditions, compared with real-time control systems which use simpler transfer function models and must undergo extensive trial and error testing. A disadvantage of this approach is that use of real-time control adds a new source of complexity and possible numerical instability to the model. Cassar and Dettmar (1996) describe a real-time control system using EXTRAN as the transport model that determines the state of the system; the decision system is based upon optimization of a linear system once the state has been determined. Vitasovic, Swarner, and Speer (1990) describe the development of a combined real-time control system and dynamic stormwater system model for the City of Seattle. This model can handle surcharging of manholes and other nonlinear flow phenomena.

5.2.2.4.1.1 Research Needs

Nelen (1994) introduces a model to assess the performance of a system using real-time control. The optimal combination of models and real-time control in a hybrid approach still must be determined. Interaction with large-scale real-time control research activity in Europe would promote the use of this method in the United States. A possible link with existing research is that such hybrid models could be evaluated in the context of determining the possible optimal level of aggregation.

5.2.2.4.1.2 References

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Pleau, M., Tremblay, M., and Colas, H. (1996) A simple approach for the diagnosis and the design of sewer networks for real-time control applications. *WEF Urban Wet Weather Pollution-Controlling Combined Sewer Overflows and Stormwater Runoff.* Alexandria, VA: Water Environment Federation.

Vitasovic, Z., Swarner, R., and Speer, E. (1990) Real-time control system for CSO reduction. *Wat. Environ. Technol.* 2 (3): 58–65.

5.2.2.4.2 Stochastic Simulation

Trotta, Labadie, and Grigg (1977) describe a stochastic adaptive control model developed for the city of San Francisco for use in predicting runoff for use in an automatic control system. They found that, even with a high degree of error in the forecast, the system's overflow performance improved.

Todini (1988) provides a good overview of the classification of modeling, including stochastic models; and includes a proposal for future directions of modeling research. Scholz (1996) advocates using urban hydrologic and water quality data to fit an autoregressive moving average (ARMA) (also known as Box/Jenkins) stochastic model. An advantage of this technique is that the results are inherently grounded in real data; *i.e.*, unrealistic model predictions are avoided.

Schaarup and Hvitved (1994) used MOUSE-DOSMO to model dissolved oxygen depletion in rivers receiving combined sewer overflows. Known statistical distributions for rainfall and input parameters were sampled from a Monte Carlo analysis with repetitive runs of the model to find a range and probability of extreme events for the concentration of dissolved oxygen in rivers. Gyasi-Agyei and Willgoose (1997) developed a hybrid technique which combines two random process models. The two models were the jitter model, which attempts to improve the fit of a point process model, and either a nonrandomized Bartlett-Lewis rectangular pulse model or an autoregressive model. The hybrid model performed substantially better than the Bartlett-Lewis model alone.

5.2.2.4.2.1 Research Needs

Stochastic models must become more integrated with existing software, to make them more available. Then researchers will find their use in conjunction with statistical techniques more practical so that the linkage is better between the deterministic and stochastic processes.

5.2.2.4.2.2 References

Gyasi-Agyei, Y., and Willgoose, G.R. (1997) A hybrid model for point rainfall modeling. *Water Resources Research* 33 (70): 1699–1706.

Schaarup, J. K. and Hvitved, J/T/ (1994) Causal stochastic simulation of dissolved oxygen depletion in rivers receiving combined sewer overflows *Water Sci. Technol.* (G.B.) **29** (1–2): 191–198.

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Trotta, P. D., Labadie, J. W., and Grigg, N. S. (1977) Automatic control strategies for urban stormwater. *J. Hydraulics Division* **103**: 1443– 1459.

5.2.2.4.3 Neural Network

Neural networks are a set of artificial intelligence techniques that are being used for function approximation and pattern recognition in wet weather flow research. Recurrent neural networks are the predominant subtype being used in the stormwater modeling field because these networks can simulate dynamic systems. The typical way in which neural networks are used includes an initial training phase in which the neural network adapts itself by testing itself against the available data record. After training, the model can then be used for prediction. Adaptive neural networks allow the system to modify itself based on the network's own performance at predicting events. Because of its reliance on data, and the empirical nature of neural network technology, it is frequently used in areas where physical processes are poorly understood. According to Bertrand-Krajewski et al. (1996) and Gong, Denoeux, and Bertrand-Krajewski (1996), the predictive effort is enhanced by introducing *a priori* information, or knowledge, or a kind of "gray box." The authors developed a neural network approach to assist in modeling the transport and flow of solids in sewer networks. Rabasso and Rosell (1996) use neural network techniques for quick forecasting of rainfall and flow within the sewer network. By enabling quick forecasts of peaks, it is possible for the decision framework of combined sewer overflows to be improved. Kroa and Chocat (1993) use neural networks to assist in the prediction of anticipated rainfall events within a real time controlled sewer system. Cancilla and Fang (1995) use neural networks, principal component analysis, and universal process modeling techniques to determine the concentration variability of selected complex organic constituents at and between specific locations along the Niagara River.

5.2.2.4.3.1 Research Needs

There are many applications of neural networks in which the network is used either in competition with or to complement a deterministic physically based model. There are very few instances of neural networks associated with stormwater modeling. More work needs to be done to determine the optimum combination of the two technologies; *i.e.*, when is it better to research the physical processes involved so that algorithmic models can be written as opposed to measuring the system extensively and using the neural net "black box" approach.

5.2.2.4.3.2 References

Bertrand-Krajewski, J.-L., Gong, N., Ding, X., Denoeux, T., and Clemente, M. (1996) Neural networks for flow and pollutant transport modeling in sewer systems during wet weather. *WEF Urban Wet Weather Pollution-Controlling Combined Sewer Overflows and Stormwater Runoff.* Alexandria, VA: Water Environment Federation.

Cancilla, D. A., and Fang, X. (1995) The use of neural networks, principal component analysis and universal process modeling for the interpretation of environmental data. James, W. ed., *Advances in Modeling the Management of Stormwater Impacts.* Guelph, ON, Canada: Computational Hydraulics International.

Gong, N., Denoeux, T., and Bertrand-Krajewski, J.-L.(1996) Neural networks for solid transport modelling in sewer systems during storm events. *Water Sc.. Technol.* (G.B.) **33** (9): 85–92.

Kroa, A., and Chocat, B. (1993) For a real-time control of sewerage systems: Validation of rainfall data with artificial intelligence tools (expert systems and neural networks). *Proceedings of the 7th International Conference on Urban Storm Drainage,* Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

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5.2.2.4.4 Calibration of Transport Models Using Improved Databases

Improved wet weather transport prediction is but one of many advantages that would result from a systematic, comprehensive wet weather database. Such a database would include critical measurements from a various climates, land uses, etc. Pollutant transport models may benefit from a comprehensive database by enabling researchers to access consistent data from similar situations. This may be especially important when using statistical relationships to predict gross wet weather pollutant transport to receiving waters.

Driver and Tasker (1990) report an example of a large-scale urban wet weather flow database constructed after data had been collected. The purpose of this work was to maximize the benefit from existing data and develop statistical models of runoff quality on a regional basis. The authors used a national database made up of data collected by the U.S. Geological Survey and the US EPA to develop statistical models of urban runoff concentrations and loads. The U.S. Geological Survey database was made up of two existing databases (Driver and Tasker, 1985; Mustard et al., 1987) and included data from 1,123 storms for 98 urban stations in 20 metropolitan areas (Driver and Tasker, 1990). The US EPA database included information from the Nationwide Urban Runoff Program and consisted of 1,690 storms for 75 urban stations in 15 metropolitan areas (Driver and Tasker, 1990).

A great deal of valuable information was gleaned from existing data collected by different agencies for different purposes. Such data should be standardized in recognition of possible future uses of the data, so that maximum benefit can be gained from the data.

5.2.2.4.4.1 Research Needs

Future improvements in wet weather performance could be assisting from use of a cross-sectional relational database. However, to maximize the usefulness of such a database, standards must be developed to guide monitoring. Ad hoc monitoring efforts have thwarted many attempts to develop a coordinated database spanning a wide range of applications. Care must be taken to ensure that data collected in the future meet rigid but cost-effective standards. Therefore, the first step in developing databases for use in wet weather applications must be the standardization of monitoring. This should be done in light of possible uses of the data once collected, such as model calibration. In addition, the applications, such as transport models, should be adaptable to this calibration data, i.e. both the databases and the applications should be standardized enough to ensure reliability, but flexible enough to allow project-specific modification.

5.2.2.4.4.2 References

Driver, N.E., and Tasker, G.D. (1993) *Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United State,* USGS Water-Supply Paper 2363. Denver CO: U.S. Geological Survey.

Driver, N.E., Mustard, M.H., Rhinesmith, R.B. and Middleburg, R.F. (1985) *U.S. Geological Survey Urban Stormwater Data Base for 22 Metropolitan Areas throughout the United States,* USGS Open-File Report 85-337, Denver, CO: U.S. Geological Survey.

Mustard, M.H., Driver, N.E., Chyr, J. and Hansen, B.G. (1987*) U.S. Geological Survey Urban-Stormwater Data Base of Constituent Storm Loads, Characteristics of Rainfall, Runoff, and Antecedent Conditions, and Basin Characteristics.* USGS Water Resources Investigation Report 87-4036, Denver, CO: U.S. Geological Survey.

5.2.2.5 Linking Surface and Subsurface Phenomena

Mull (1996) determined the range of discharge from leaky sewers to groundwater in Hannover, Germany, to be from 2.6 million to 9.4 million cubic meters per year using water balance, groundwater balance, and tracer studies. Morita, Nishikawa, and Yen (1996) developed the governing equations for the combination of surface flow and an infiltration trench. The authors' approach was to use a two-dimensional unsteady surface flow solution to the St. Venant equation coupled with a modification of the Richards equation for three-dimensional unsaturated unsteady subsurface flow. They introduce a new parameter, infiltratability, which is compared with rainfall intensity. The computer model based on this algorithm yielded reasonable results for this situation. SWMM (Huber and Dickinson, 1988) contains a one-dimensional, two-zone (saturated and unsaturated) groundwater routine to model infiltration. The purpose of this routine was to better handle areas, such as South Florida, where the primary means of runoff disposal is by infiltration rather than by surface transport.

Wada and Miura (1993) developed a simple, one-dimensional surface and unsaturated groundwater model to simulate a paved surface running off to an infiltration trench. Mushtaq, Mays, and Lansey (1993) developed a surface and subsurface model for operation of a series of recharge basins, and applied a nonlinear objective function and control theory to develop operational policies for the basins. The model was based on a Phillips/Green-Ampt infiltration model coupled with Darcy's equation for groundwater flow used for soil moisture redistribution, and a kinematic wave model for surface flow. Dunn et al. (1996) describe the NELUP decision-support system (DSS); this paper focuses on the hydrologic models used in the system. A groundwater flow component with coupled equations to river flow is included in the DSS.

5.2.2.5.1 Research Needs

Typically, recharge is the least known input variable in a groundwater flow model. It depends upon precipitation, infiltration, evapotranspiration, and various other factors that vary both spatially and temporarily. An unfortunate obstacle in this problem is the time scale; i.e., urban hydrologic models usually have time steps on the order of seconds or minutes, whereas groundwater flow models typically have time steps on the order of days, weeks, or even months. A more fundamental understanding of the water balance must be attained to formulate more general simulation tools. Until then, research of specific homogeneous sites will prove useful for limited situations.

5.2.2.5.2 References

Dunn, S. M., Mackay, R., Adams, R., and Oglethorpe, D. R. (1996) The hydrological component of the NELUP decision-support system: An appraisal. *J. Hydrol.* 177 (3/4): 213–235.

Huber, W. C., and Dickinson, R.E. (1988) *Storm Water Management Model, Version 4: User's Manual,* US EPA/600/3-88/001a.

Morita, M., Nishikawa, R., and Yen, B. C. (1996) Application of conjunctive surface–subsurface flow model to infiltration trench. *Proceedings of the 7th International Conference on Urban Storm Drainage,* Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

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Wada, Y., and Miura, H. (1993) Prediction and estimation of stormwater runoff control by the combined stormwater infiltration facilities with simulation model. Field, R. O'Shea, M. L., and Chin, K. K., eds., *Integrated Stormwater Management.* Boca Raton, FL: CRC Press, Inc.

5.2.2.6 Linking with Atmospheric Models

Thielen and Creutin (1996) linked an urban hydrologic model with an atmospheric model. The problems they encountered were describing soils, roughness, heat fluxes, and infiltration processes to the degree necessary to satisfy the atmospheric model.

Lin (1994) developed the atmospheric and sediment deposition model (ASDM), which is a combined water column and surface sediment advection and dispersion model capable of modeling transport processes that include sedimentation, sorption, and air–water diffusion, dry and wet deposition. The model was used to analyze several hot spots of mercury in the Detroit River.

According to Epstein and Ramirez (1994), global climate models (GCMs) work on a different scale which does not allow direct linkages to smaller-scale hydrologic models. To overcome this problem, the authors use daily spatial disaggregation techniques within the Upper Rio Grande River Basin in Colorado, preserving spatial variability, while analyzing temperature and precipitation records. The authors could then predict seasonal changes in runoff, soil moisture, evapotranspiration, as well as snowpack. An example of using a catchment model linked with an atmospheric model is given in Viney and Sivapalan (1996), and another can be found in Yates (1996). Both of these examples use water budget analysis to link the two modeling technologies on a spatially gridded scale.

5.2.2.6.1 Research Needs

More work must be done with respect to scaling issues between atmospheric models, water balances, and urban stormwater modeling. At present, the GCMs use a very large grid that does not refine or adapt itself over differing hydrologic regions, such as urban areas, so that much of the urban wet weather flow phenomena are lumped into larger regional hydrologic phenomena.

It is debatable whether urban hydrologic processes are appropriately simulated in this fashion, even at large time and space scales. More work must be done at the GCM level in terms of adapting to urban areas, and possibly to an adaptive grid size. Water budget analysis is the key link between atmospheric and urban wet weather flow models.

5.2.2.6.2 References

Epstein, D., and Ramirez, J.A. (1994) Spatial disaggregation for studies of climatic hydrologic sensitivity. *J. Hydraul. Eng.* **120** (12): 1449–1469.

Lin, C-C. R. (1994) Modeling the Detroit River Aquatic and Sediment Systems, Master's thesis, Wayne State University.

Thielen, J., and Creutin, J.D. (1996) Problems related to the numerical coupling of an atmospheric model with an urban hydrological model. *Proceedings of the 7th International Conference on Urban Storm Drainage,* Hannover, Germany. IAHR/IAWQ Joint Committee Urban Storm Drainage.

Viney, N. R., and Sivapalan, M. (1996) The hydrological response of catchments to simulated changes in climate. *Ecol. Model.* **86** (2–3): 189–193.

Yates, D. N. (1996) WatBal: An integrated water balance model for climate impact assessment of river basin runoff. *Water Resources Dev.* **12** (2): 121–139.

5.2.2.7 Solids in Sewers/Sewer System Modeling

Existing models cannot adequately handle the generation, deposition, settlement, erosion, and transport of solids within sewers. This is primarily due to a fundamental lack of understanding in the physics of solids behavior, according to Gent, Crabtree, and Ashley (1996). The authors review the current research in the area of sewer sediments, as well as implementation in sewer flow quality models, and suggest linking "field data collection, theoretical and laboratory studies, and model/software development" to assist in the success of current research. Schafer (1994) provides practical information necessary for use in models and design in the interim.

According to Bertrand-Krajewski et al. (1996), the predictive effort is enhanced by introducing *a priori* information, or knowledge, or a kind of "gray box." Bertrand-Krajewski et al. (1996) developed a neural network approach to assist in modeling the transport and flow of solids in sewer networks. The model compared favorably with predicted modeled results (MOUSE was the hydraulic model).

Schmitt and Zimmerman (1996) describe the model HAuSS developed to include micropollutant, sediment, and solids transport in sewers. Koelling (1996) used a finite element method to simulate the velocity field within an irregularly shaped sewer. This enables accurate flow estimation (typically depth is measured) even during backwater conditions. Swaffield and McDougall (1996) developed an unsteady flow model of a drainage system network using partially filled pipes capable of predicting flow depth and rate and solid velocity, and show how such a model can be used in decision making in the area of new development design. At present, the more empirical input/output and probabilistic characterization of solids behavior may need to be reevaluated. Studies in this area need to include some sampling and characterization of solids at the location in question.

5.2.2.7.1 Research Needs

To progress in this area, monitoring and modeling of solids transport in sewers must be developed conjunctively. Fundamental understanding of solids behavior in sewers is lacking, and research should be devoted to this area. Significant research is underway in this area in the United Kingdom, and modeling efforts in should proceed and should be supportive of the physical research on solids.

5.2.2.7.2 References

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5.2.3 Integrated Decision Support Systems

A decision support system assists in bridging the gap between data and models to solve difficult, partially undefined problems. A thorough background on decision support systems and its application to reservoir decisions can be found in Jamieson and Fedra (1996a, b) and Fedra and Jamieson (1996). This series of articles describes the conceptual design, planning capability, and example application of the Water Ware DSS, a complex river basin DSS that combines "GIS, a geo-referenced database, groundwater flow, surface water flow, hydrologic processes, demand forecasting, and water-resources planning." Reservoir operation and management was one of the first areas in which DSSs were applied. Because of the complicated decision criteria governing urban wet weather flow management, Davis et al. (1991) studied a prototype DSS developed to analyze the impacts of different catchment policies. Driscoll (1993) developed a DSS to assist highway engineers in determining which construction sites would contribute to a receiving water quality problem. Azzout et al. (1995) discuss a DSS that would assist in the feasibility determination of alternative techniques in urban wet weather flow management. Lavellee, Marcoux, and Bonin(1996) describe a real-time control system developed for the Quebec urban area to manage a wet weather flow system to minimize CSOs. The unique data needs and system architecture of the real-time control system support many of the concepts of DSS because of the demand for timely decisions relating to large datasets.

5.2.3.1 Research Needs

Current work in decision support systems has focused on use of Unix-based minicomputer systems. Typical costs for these systems may be prohibitive for non-research–related activities. Software and development costs can also be high. Urban wet weather flow management has tended to focus more on PC-level technology, at a much smaller spatial and temporal scale, and at significantly smaller investment levels. This is primarily due to the fact that many of the users are small consulting firms or municipal governments. One aspect of current decision support systems is the lack of integration with existing stormwater modeling technology. Research in the development of decision support of urban stormwater systems should focus on use of personal computers linked to external databases over the internet. This has become possible recently with the increasing speed and processing power of personal computers, and advances in software such as GIS. DSS for urban stormwater needs to incorporate real-time control and the ability to effectively handle large databases and rapid evaluation of control options.

5.2.3.2 References

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5.2.3.3 Integrate GIS to Refine Spatial Analysis Capabilities

The development of geographical information system (GIS) software technology is dramatically changing the practice of municipal engineering. According to Shamsi, Benner, and Fletcher (1995), more than 70% of the information used by local governments is geo-referenced. Shamsi, Benner, and Fletcher (1996) describe how ArcView, a GIS software package, can be used for a variety of GIS-related linkages to urban stormwater models and data management, including AM/FM systems. For an overview and description of GIS and hydrologic modeling, primarily focused on large-scale distributed watershed modeling, see Singh and Fiorentino (1996). Hauber and Joeres (1996) describe how GIS was used as a preprocessor for the source loading and management model (SLAMM) to estimate pollutant loads in urban areas. A case study of Plymouth, Minnesota, is included. Smith (1993) developed an urban hydrologic model using GIS with a distributed grid approach. Bellal, Sillen, and Zech (1996) use a digital terrain model approach, combined with a distributed grid, and compute a water balance within each grid cell. They found that the model compared well with other models, such as SWMM. Herath, Musiake, and Hironaka (1996) developed a GIS-based gridded urban area water budget, using simplified homogeneous units within each grid. They argue that the distributed hydrologic models capable of reflecting urban heterogeneity are needed although their model agreed well on a large scale. Litchfield (1994) compared various levels of abstraction in hydrologic models to observed data, using GIS to evaluate input parameters in finer levels of abstraction, i.e., down to the parcel level. The author found that the finest grid fit the pollutographs and hydrograph peak best, whereas the intermediate grid fit the storm volume best.

5.2.3.3.1 Research Needs

Several new GIS tools are now available that allow easier and better integration of GIS into stormwater modeling. A promising tool, mapobjects by ESRI, essentially allows a GIS object to be used in a Visual Basic or Visual C++ program. Similar tools from other vendors are also available. Either of these programs supports mixed language processing, including legacy Fortran 77, so development of an integrated GIS/stormwater model is probably easier now than it ever has been. Another avenue of research would be to continue the work of Litchfield (1994) with comparisons to continuously measured data, i.e., a real-time monitoring system in which GIS developed model parameters, and combined with a very fine rainfall/runoff spatial data system. An important research question is the effect of the finer grid on simulations—should some of the hydrogic algorithms or routing characteristics at this level be modified?

5.2.3.3.2 References

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5.2.3.4 Interface Simulation and Optimization Models

Medina and Jacobs (1995) integrated simulation and optimization in a wet weather flow design modeling study that integrated failure and reliability analysis into its decision criteria. Nix and Heaney (1988) describe a procedure for continuous simulation and generation of production functions, which are then optimized by a variety of procedures. Segarra (1995) used a similar optimization analysis procedure. Production functions were developed for storage capacity and release rate, which were then optimized using runoff or pollutant trap efficiencies as a constraint. Gall, Averill, and Weatherbe (1997) describe a process modeling and simulation study with CSOs. They give an overview of dynamic simulation and optimization.

5.2.3.4.1 Research Needs

A promising research area of optimization is the use of genetic algorithms. This technique has already been applied to pipe network models (Dandy, Simpson, and Murphy, 1996), as well as river management decisions (King et al., 1995). The technology has yet to be widely applied to the complex optimization problems of urban wet weather flow. With the advent of Microsoft Windows and object-oriented programming, the interface between simulation and optimization has become easier to achieve. Tools are now available that permit off-the-shelf software for the most difficult portions of programs. Directed research into these areas may significantly increase the ability to link optimization and simulation.

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5.2.3.5 Integrated DSS for Overall Watershed

5.2.3.5.1 Watershed Models

Watershed models combine the ability of hydrologic/hydraulic routing models such as SWMM with a receiving water model such as WASP or RIVMOD. This integration helps track sources of pollutants and nutrient loadings into receiving waters. Wool, Martin, and Schottman (1994) developed a linked watershed/waterbody model that integrates these models so that they can be run simultaneously. Kort and Cassell (1993) developed an object-oriented watershed model using STELLA, a process simulation language and program. Pabst (1993) outlines the objectives of the U.S. Army Corps of Engineers in the NEXGEN project. In this project, two hydrologic models, HEC-1 and HEC-2 are recast in an object-oriented manner as HEC-HMS and HEC-RAS. Both of these tools have been used extensively in watershed management. Schroeter et al. (1996) describe a long-term integrated watershed management study in southwestern Ontario, Canada. The authors developed a continuous in-stream temperature model that integrates information from runoff models, evapotranspiration, channel routing, reservoirs, recharge, and ecosystem information (such as vegetated canopy). Ford and Killen (1995) developed a DSS for the Trinity River watershed of Texas. The system combines a graphical user interface with HEC-1 and HEC-5 for runoff and reservoir system modeling, respectively, and, performs the following tasks:

- Retrieve, process, and file rainfall and streamflow data;

♦ Estimate basin area rainfall, update model parameters, and forecast runoff; and

♦ Simulate operations in order to forecast regulated flows basinwide.

The main objective of this system is to improve flood prevention and control.

5.2.3.5.1.1 Research Needs

Many of the existing tools are designed to analyze only a portion of the watershed. Cross-cutting, interdisciplinary models and decision support systems should be developed that cover entire watersheds and can enhance communication among professionals. All watersheds are complex, but, those in urban areas in particular have another layer of infrastructure and management practices to deal with as well. Heaney et al. (1998) offer the Boulder Creek watershed as a possible candidate for such study.

5.2.3.5.1.2 References

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5.2.3.5.2 Ecosystem Models

Lhotka (1994) and Chapra (1996) describe an individual-oriented ecosystem aquatic ecosystem model capable of reproducing predator–prey relationships. Heringa et al. (1995) developed an object-oriented lake ecosystem model called LAKE. The model integrates most water resources processes with lake ecosystem processes. Berry, Hazen, and Flamm (1996) developed the LUCAS model, which "can integrate ecological and socioeconomic information for adaptive approaches to landscape management." The model is constructed with object-oriented techniques, and is combined with the GRASS GIS system. LUCAS predicts ecological impacts, such as spatial species distributions, as the result of projected land-use changes. Ford, Running, and Nemani (1994) developed the Rhessys model, a regional, hydro-ecological simulation system, which is a macro level biogeochemical model that uses raster-based input information, such as soils or leaf area index, to model ecosystem dynamics. Leonov, Litvinov, and Razgulin (1996) developed an ecological model of the Rybinskoe reservoir ecosystem based on the biogeochemical fluxes of organogenic elements (carbon, nitrogen, and phosphorus). Input parameters into the model included water surface temperature and illumination and hydrologic regime. Output includes carbon, nitrogen, and phosphorus fluxes, production, and destruction cycling. The authors explain several annual periodic variations, as well as regional peculiarities with the model.

5.2.3.5.2.1 Research Needs

A promising area of research is the use of satellite data measures to develop relationships on fluxes of nutrients, energy, and water within an ecosystem. A possible critique on the ecosystem models is the scale involved; i.e., the scale is usually large because satellites collect data on a large grid. As computer technology advances, the scale will decrease; and at some point it may be possible to use irregular grids such as watersheds and urban areas. Another area of integration is to use watershed models as building blocks in larger ecosystem models.

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5.2.3.6 Risk Management Methodologies

Moser (1993) describes the U.S. Army Corps of Engineers' procedure to estimate flood damages based upon stage–damage–discharge curves. The author describes the use of new software and Monte Carlo simulation techniques to predict the relative uncertainty in each of these estimates. Arnbjerg-Nielsen and Harremoes (1996) applied these same techniques to urban storm drainage and found that, for most cases, the dominant contributor to uncertainty was the description of rainfall, followed by the prediction of runoff. However, in the case of extreme event prediction of chemical oxygen demand (COD) from CSOs, the uncertainty in the estimation of COD concentration was dominant. Novotny (1996) describes an analytic procedure for calculating the risk associated with wet weather discharges to aquatic ecosystems. Lei and Schilling (1996) use a combination of Monte Carlo simulation followed by multiple linear regression to estimate the undercertainty of models based upon the distribution of input parameters (uncalibrated). Heaney, Wright, and Samsuhadi (1996) describe an integrated risk management approach to urban wet weather flow quality management within the context of a multipurpose stream, Boulder Creek, in Boulder, Colorado, which also serves such additional uses as recreation, wastewater treatment dilution, agriculture, and instream flow augmentation and restoration. Risk analysis of the flow at the wastewater treatment plant shows that the covariance of concentrations of BOD and TSS are strongly related to flows, indicating that dilution ratio increases as the probability of an overflow increases. This increasing dilution ratio substantially decreases the risk of impacts from overflow events. Bulkley (1993) describes the process of developing acceptable criteria for determining permit requirements for combined sewer overflows (CSOs), based on the tradeoff between cost of increased storage and reduced risk from overflows. Finally, Line et al. (1993) review the risk-assessment methods appropriate to nonpoint-source pollution, balancing the economic risk of agriculture versus the environmental risk of nonpoint-source pollution.

5.2.3.6.1 Research Needs

US EPA (1996) set forth a strategic plan in the areas of characterization and problem assessment, watershed management, toxic substances impacts and control, control technologies, and infrastructure improvement. For the most part, these research needs are included within other areas.

5.2.3.6.2 References

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5.3 Watershed Management Linkages

Interest in watershed management has waxed and waned over the past century. The concept of integrated water and land management was first articulated in the western United States by John Wesley Powell in a report to Congress in 1878 (Peterson, 1984). However, Congress rejected his idea and continued to use an ad hoc approach to authorizing projects. During the 20th century, interest in watershed planning has come and gone several times. Following World War I, unified planning at the river-basin scale flourished with major studies and implementation on numerous river basins, e.g., the creation of the Tennessee Valley Authority. The National Resources Planning Board provided the leadership for these efforts (Viessman and Welty, 1985). Increased environmental awareness during the 1960s and 1970s led to expanded efforts to evaluate water quality and related problems on a regional level. During the 1980s, water resources problems were addressed primarily by a command and control approach. A strong move back to the watershed management approach began a few years ago, e.g., see the *Proceedings of Watershed '93 and Watershed '96* (WEF, 1993; 1996). US EPA (1991) has taken a strong interest in the watershed approach. While it is axiomatic that integrated, holistic, sustainable infrastructure systems are desirable, demonstrated success stories of how such systems might function effectively are rare (Heaney, 1993).

St. John et al. (1996) described using hydrodynamic and water quality models to evaluate the overall impact of dry and wet weather loads on dissolved oxygen in receiving waters near New York City. Brosseau (1996) explained how the Bay Area Stormwater Management Agencies Association in the San Francisco area operates. This association's membership comes from seven stormwater agencies in the area. A major motivation for watershed-based approaches is economic efficiency. Brewer and Clements (1996) described how organizations formed a consortium to share the cost of monitoring at the watershed scale. Another source of savings from watershed management is to remove pollutants within the watershed in the most cost-effective manner. Market-based pollutant upstream/downstream trading has emerged as a potentially valuable mechanism. Methods for discharge trading and case studies were presented by Podar et al. (1996). Frederick et al. (1996) estimated the benefits of stormwater detention systems as increased property values due to the waterfront amenity value. They include the results of property valuations in many areas. Marx, Leo, and Heath (1996) described how a watershed-based approach has resulted in more cost-effective CSO control in Boston. Weiss and Lester (1996) outline how watershed ideas can be used to address sanitary sewer overflow problems within US EPA's regulatory program. Brady (1996) summarized the accomplishments of the first 5 years of US EPA's watershed protection approach. Stumpe and Hamid (1996) described how applying a watershed approach can develop more cost-effective SSO control programs. Urban wet weather flow is but one of many impacts in urban watersheds. Studies in Boulder, Colorado (Heaney, Wright, and Samsuhadi, 1996) and in Quebec city watersheds (Vescovi and Villeneuve, 1996) illustrate the complexity of urban watersheds. This complexity may be typical for urban areas because mankind invariably significantly modifies the watershed system. Roesner, Mack, and Howard (1996) describe an integrated master planning approach for wet weather flow management in a new development near Orlando, Florida.

Stephenson (1996) compares the water budgets of an undeveloped catchment with an urbanized catchment in Johannesburg, South Africa. The results show the expected increase in direct runoff and the need to import water for water supply. Nelen and Broks (1996) describe the planning of a new development for about 10,000 people in Ede, Netherlands. The three underlying environmental principles are sustainability, quality, and ecology. This area has a high groundwater table so groundwater management is an important part of the project. They plan to incorporate water-conserving hardware and divert the more polluted stormwater into the sanitary sewer. They are also considering a dual water supply system. Escartin (1996) provides an overview of Spain's use of the watershed approach since 1926 to manage water more efficiently.

Early watershed planning efforts focused on developing "master plans" which, once approved, served as a blueprint for management in the basin. Before computers, such efforts faced severe technological limitations in bringing together large amounts of information and systematically analyzing alternatives. The widespread availability of mainframe computers in the 1960s and associated computer-based simulation and optimization techniques led to large-scale efforts to develop "rational" master plans (Maass et al., 1962). Integrated river basin planning models were developed as early as 1971. Mays and Tung (1992) and Wurbs (1994) summarize these quantitative methods. The thrust in developing better planning methods was in devising ever-more complex models, e.g., three-dimensional lake models, nonlinear programming models. Unfortunately, the sophistication of models greatly outstripped the availability of data. Nevertheless, models have had a strong positive influence on water resources planning (Office of Technology Assessment, 1982).

In summary, research in watershed management is quite active, particularly in the modeling and DSS area. However, focused research is still needed in the development of a watershed assessment method, development of long-term watershed case studies, development of an urban research catchment network, and development of watershed-based water quality standards. A detailed literature review and summary of the needs in each of these areas follows.

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5.3.2 Watershed Assessment Methodology

Brelot, Chocat, and Villessot (1996) describe a prediagnostic computer tool to determine the information needs to be addressed in a combined waterway/watershed impact/drainage system study. Lawrence (1996) emphasizes the need for ecosystems to be the building blocks of water management. Increasingly, biological indicators are being used as measures of watershed health. Development of streamflow and loading criteria require knowledge of geomorphological, hydraulic, and ecological sustainability. This emphasizes the need for total water cycle-based modeling. Young, Farley, and Davis (1995) describe an assessment model of a watershed that uses land-use changes in input values, and calculates average annual loadings within the catchment. This tool can be used to identify, within the context of public involvement, those areas where a more detailed model study should be conducted. Donigian, Huber, and Barnwell (1996) describe the available models of nonpoint-source water quality used in watershed assessment, such as SWMM, HSPF, STORM, CREAMS/GLEAMS, SWRRB, and AGNPS. VerBeek et al. (1996) describe a decision support system tool used for policy analysis decisions within a watershed.

5.3.2.1 Research Needs

To date, there is no generally accepted watershed assessment method. Researchers tend to address a problem from within a discipline, so the solution reflects their disciplinary bias. Modeling tools tend to be concentrated within a given discipline, as well. Simulation technology should be updated to current computer technology to reach a broader audience. This may include the use of decision support systems. Case studies could be used to evaluate such a method.

5.3.2.2 References

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5.3.3 Long-Term Watershed Case Studies

Roth (1995) presents a watershed-based case study of Bear Canyon, in the Albuquerque, New Mexico area and describes the impact of past and present land use on the watershed, governmental measures to rectify these problems, and what best management practices can be employed to limit stormwater pollution. Jensen et al. (1995) discuss the Chain of Lakes, approximately 2 miles south of Minneapolis. The lakes are an important recreational resource; however, historical trends indicate long-term degradation. The authors discuss a watershed-based monitoring and assessment program, and what recommendations the program makes. Conry (1994) describes the Oyster Creek lake system, created by a series of dams, and its water quality. The author describes the citizen involvement—created as a result of the increased water level resulting in desirable waterfront property. Arteaga and Bartel (1994) describe a watershed monitoring study done for the city of Quincy, Florida. Water quality for drinking water supply is extremely variable due to turbidity and agricultural NPS pollution. Continuous stormwater quality modeling evaluated the effectiveness of control options, such as reservoirs and land-use controls. Wegener, Kunkel, and Wulliman (1990) describe the Shop Creek drainage outfall system, which was constructed at a cost of $671,000. The Shop Creek watershed comprises approximately 640 acres, draining into the Cherry Creek Reservoir, an important metropolitan recreation and drinking water resource. This project consisted of 3,000 feet of eroded stream stabilization and construction of a 4.8-acre-feet of continuously wet detention storage, with another 9.1 acre-feet of extended dry storage as well. The watershed was monitored extensively and it was determined that capturing phosphorus load, particularly the fraction of suspended phosphorus attached to fine sediments, was a priority. Scro (1994) describes the Navesink River Nonpoint Source Shellfish Protection Program, a multi-year monitoring effort, the goals of which were to reduce bacterial contamination of shellfish in the river, to improve agricultural productivity, and to mitigate nutrient and sediment loading in downstream reservoirs.

5.3.3.1 Research Needs

The most significant need is for a long-term commitment to monitor urban catchments. Shop Creek, in Aurora, Colorado, has an extensive water quality and quantity database of an urban watershed through the entire development cycle. However, gaps in this database result from limitations in funding, which has been almost exclusively funded on a local level. Many similar watersheds, such as the city of Boulder's, have some data; the limitations occur because of shifts in municipal priorities. Possible research funding into basic data collection and archiving would most certainly increase the amount of available data to evaluate long-term watershed impacts.

5.3.3.2 References

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5.3.4 Urban Research Catchment Network

Huber et al. (1982) collected a storm event database of urban rainfall runoff quality data for 48 catchments in 16 urban areas. They provide hydrologic data for 25 catchments in 15 urban areas. They statistically analyze each parameters. Thorolfsson (1996) describes the Slandsli Research Catchment, a collaboration between the Department of Hydrologic and Environmental Engineering of the Norwegian University of Science and Technology, Trondheim, and the municipality of Bergen. Within the catchment are side by side conventional and infiltration systems for stormwater disposal. The results showed that using infiltration reduced surface runoff by 70%, maintained the predevelopment annual groundwater level after development, and cost about 30% less. Mitchell, Mein, and McMahon (1996) describe a water budget approach to integrated water management in Australia. They budgeted water at the individual parcel, neighborhood, and wider catchment scales. Jack, Petrie, and Ashley (1995) advocate the inclusion of the entire catchment in CSO modeling so that the optimal "hydraulic, economic, and environmental solution may be found."

5.3.4.1 Research Needs

In the United States, a few municipalities have established partial monitoring of catchments for water supply and pollution control needs (see section 5.3.3: Shop Creek, in Aurora, Colorado); however, there is no organized national effort; data for these types of sites are not widely publicized. Thus, this remains a pressing research need. This research could tie to the NSF LTER experimental watershed program. This could be combined with long-term case studies of environmentally friendly developments.

5.3.4.2 References

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5.3.5 Watershed-Based Water Quality Standards

Stecker et al. (1994) summarize the South Carolina watershed-based water quality program. The watershed-based approach recognizes the need for coordination with activities such as "monitoring, problem identification and prioritization, water quality modeling, planning, and permitting." Schiff and Stevenson (1995) discuss the watershed-based monitoring approach of wet weather runoff in the San Diego, California, area. The findings were that the event mean concentrations of pollutants were lower than national averages. Monitoring also included 7-day chronic toxicity testing of *Ceriodaphnia*. During this study, fecal coliform bacteria from stormwater runoff resulted in closing the beach at Mission Bay.

The key aspects of nonpoint source pollution (NPS) in the context of watershed management can be found in Line et al. (1993). The authors review effluent trading to allocate pollutant loadings based upon a least-cost framework. They review impacts of NPS on receiving waters, as well as mathematical models appropriate to them; and controls and best management practices, as well as risk-assessment methodologies. Warwick, Cockrum, and Horvath (1997) give a method for estimating NPS loads and measuring water quality impacts using WASP5, a dynamic surface water quality model. Liao and Tim (1997) tightly couple an agricultural NPS model (AGNPS) with an Arc Info GIS system to develop an interactive watershed modeling environment.

5.3.5.1 Research Needs

A comprehensive statistical analysis of the performance of water quality-based standards in terms of both spatial and temporal dimensions must be done, with careful attention to intrastate as well as interstate variations, as program lines are set up along state levels. Watershed to watershed variability would make this analysis somewhat complex., but, common characteristics of watershed health could be used.

5.3.5.2 **References**

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CHAPTER 6.0

REGULATORY POLICIES AND FINANCIAL ASPECTS

This chapter summarizes current work in regulatory policies and financing for management of urban wet weather flow, including regulations and permits, reuse and water resources, financing and cost analysis, benefits of urban wet weather flow management, and education and outreach. The research topics identified in Table 2–8 were organized into the outline as shown in Table 6–1. This grouping accommodates the overlap of some topics and the lack of available literature for others. Many of the other topics were combined into a single subsection. New sections, such as Section 6.3, were added where necessary to cover the broader nature of the field.

6.1 Regulations and Permits

During the 1960s and 1970s, after the initial passage of the Clean Water Act and subsequent amendments in 1972, the US EPA attempted to avoid regulation of wet weather flows. Perhaps this was because of the perspective at the time to focus on areas that would have the most impact, such as sewage treatment plants and industrial point discharges, but because of the sheer volume of WWF discharges in the United States. Although urban stormwater is usually a point discharge, it was classified with nonpoint source discharges because of their dispersed spatial nature and their lack of regulatory control. During the 1980s, the US EPA decided to selectively permit stormwater discharges; this effort was chosen based upon probable pollution potential. However, the Water Quality Act of 1987 required US EPA to initiate a new effort in the urban wet weather flow field, and US EPA promulgated these interim regulations in 1990. These rules required municipal stormwater discharge permits for the first time for areas whose population exceeds 100,000. Later rules pertain to less populated areas (Roesner and Traina, 1994).

Industrial stormwater dischargers can select an individual, group, or general permit, depending upon the nature of the discharge and preference (Field et al., 1997). Because little is known of the characteristics or quality variability of a given discharge, the program, at least initially, is primarily for monitoring.

Table 6–1. Research Topics on Regulatory Policies and Financial Aspects of Urban Wet Weather Flow Management (Unprioritized)

Section	*Table 2-8 ID#*	*Research Topic*
6.1 Regulations and Permits	86	Improve EPA use attainability study methodologies
6.1.1 Preparing Effective and Implementable NPS Watershed Goals	69	Preparing effective and implementable NPS regulations
6.1.2 Determining Areas Where Regulatory Flexibility can Achieve Watershed Goals	70	Areas where EPA can provide regulatory flexibility to achieve watershed goals.
6.2 Reuse and Water Resources	79	Wet weather flow management in new urban areas
	75	How to develop sustainable watershed management programs
6.3 Financing and Cost Analysis		
6.3.1 Methods of Financing		
6.3.2 Methods of Cost Allocation	71	Methods to allocate the costs of multipurpose water projects
6.3.3 Development of Cost and Performance Data for Controls	72	Cost/performance function data for wet weather flow controls
6.4 Benefits of Urban Wet Weather Flow Management	73	Quantify benefits of wet weather flow quality control
6.4.1 Contingent Valuation	74	Contingent valuation to estimate the benefits of wet weather flow projects
6.4.2 CSO Measures of Success	76	CSO measures of success
6.5 Education and Outreach	81	Common elements of successes and failures.
6.5.1 Public Involvement, Participation Techniques	77	Feedback on public involvement, participation techniques
	87	Environmental ethics to reduce litter
	78	How to translate public desires into action?
6.5.2 Coordination of Wet Weather Flow Research Across Agencies	85	Mechanism for coordinating wet weather research across agencies
	82	Retrospective assessments of existing environmentally friendly developments
	80	Feasibility of decentralized urban water management and privatization
	83	Environmental justice in management programs
	84	Recognition of regional differences in appropriate management strategies

Roesner and Traina (1994) and Moffa, Cabral, and Ford (1996) provide an overview of current federal regulations that pertain to urban wet weather flow. Because the program is relatively new, and because available information is lacking, US EPA has given permitees latitude. This is, in part, a concern for the sheer numbers of possible permits involved; however it also reflects US EPA's philosophy on watersheds. With the latitude comes a monitoring responsibility to establish background concentrations, both within the stormwater system itself, as well as the receiving water. Some of the requirements within the program, such as calculations of annual pollutant loads to receiving waters, require modeling technology that is still being developed (Pandit and Gopalakrishnan, 1997).

Many municipalities regulate wet weather flow quantity from the perspective of flood control or a nuisance regulation. This is mainly to protect neighboring property owners and rights of ways from being damaged by excess runoff. Mazich et al. (1990) describe basin-wide stormwater management ordinances. Another good reference in this area is Debo and Reese (1995). It would be interesting to examine areas of municipal regulation for stormwater quantity that could also be used for regulation of stormwater quality. Many municipalities have become responsible for water quality at the discharge point, thus providing incentive to develop authority to control water quality at the source as well. But, many of these municipalities are not now equipped for this responsibility. A key need is to educate the municipalities' existing professional personnel. According to Pitt et al. (1997), referring to the existing framework of local regulation, "without the institutional systems to set them up and enforce them, they will not be effective." Another key area of importance is municipal financing. Most of the urban wet weather flow infrastructure currently is funded at the local level; and, in most municipalities, serious deficiencies exist. New funding sources will be critical for the success of any new regulatory programs in this area.

An important aspect of US EPA's evolving program in this area is the potential for regulatory flexibility. In the development of US EPA's program, the agency has made some deliberate policy decisions to encourage watershed-wide planning and management of urban wet weather flows. Many new areas of water quality-based exchanges could benefit municipalities. These include the concept of effluent trading within a watershed (US EPA, 1996a, b). Effluent trading to maintain water quality on a watershed level has gained momentum recently; but, the system is complex (Kerns and Stephenson, 1996). US EPA (1996b) describes the benefits of pollutant trading among the various sources within a watershed as a means of reducing costs, and a framework for watershed-based trading was prepared (US EPA, 1996a). Little and Zander (1996) conducted a cost-effectiveness study on point sources and nonpoint sources control of phosphorus in Chatfield Basin, Colorado. Podar et al. (1996) summarized progress on trading programs across the nation. Taff and Senjem (1996) offered practical measures to resolve the uncertainties associated with nonpoint-pollutant trading systems.

The urban pollution management (UPM) manual and its products are being widely used in the United Kingdom for evaluating their flooding and CSO pollution problems (Morris and Clifforde, 1996). Brashear and Drinkwater (1996) compared urban wet weather pollution management approacies in the United States with those in the United Kingdom. Lindsey, Swietlick, and Hall (1997) summarize the application of US EPA's evolving watershed philosophy to urban wet weather flow management. According to the authors, urban wet weather flow pollution remains the single largest source of water quality degradation. US EPA introduces a key area of flexibility since the Water Quality Control Act of 1987 is the concept of "use attainability," which is a pragmatic realization that, in many urban areas, certain stream lengths do not and will not meet any significant water quality standard, no matter the technology used for urban wet weather flow. According to Title 40 CFR §131.3(g), "Use attainability analysis is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in Sec. 131.10(g)." Use attainability allows the users to develop alternative criteria and treatment requirements that balance the costs of compliance with the benefits of a realistic goal.

Novotny (1996) summarizes the new use attainability analysis (UAA) procedure found in Novotny et al. (1997) which is a guide published by the Water Environment Research Foundation. US EPA (1997) applied UAA to the development of TMDLs for a 15.5-mile stream section of Boulder Creek immediately downstream from the city of Boulder's wastewater treatment plant. This analysis is an attempt to bring a holistic viewpoint to the waste-load allocation procedure. The study found that the stream water quality is impaired by a combination of factors, including discharges, urban runoff pollution, agricultural runoff, and diversions of water that could be used for dilution, for water supply for people and agriculture. A wastewater treatment plant upgrade would not alone solve the problem, and would waste community resources without measurable environmental benefit. The study recommends a combination of modest plant upgrades, best management practices, and habitat restoration to achieve a reasonable water quality standard. Michael and Moore (1996) demonstrate that the UAA procedure can be used two ways: as a way of relaxing an unnecessarily stringent water quality standard to protect the aquatic ecosystem, as well as using the analysis to demonstrate the need to protect undesignated waters.

6.1.1 References

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6.1.2 Preparing Effective and Implementable NPS Watershed Goals

Markowitz (1996) advocates continuous measurement and good communication with stakeholders to optimize water quality management including NPS and point sources. The author found toxicity testing to be of some limited value as a screening tool, but advocates the use of stream biological standards, recently established for the state of Ohio. Rumery-Betz and Taylor (1994) describe several priority lake projects in Wisconsin, including Camp and Center Lakes and Lake Mendota. The authors describe how urban land-based computer models such as WINHUSLE, BARNY, and SLAMM and lake water quality models are combined with GIS to assist in data integration as well as to keep track of land use changes within the watershed. After a 2- to 3-year planning process, a watershed plan is implemented, usually over 8 years, at a cost of $1 million to $6 million per project. Meals (1990) describes the 10-year monitoring and BMP control effort for the LaPlatte River. This project's main goal was to control shellfish pollution in downstream Lake Champlain by implementing land treatment, at a cost of $996,188, of which 71% was paid by government and 29% by landowners. Concentrations of TSS may have dropped from 10% to 60%. According to Wolf (1995), it is difficult to measure the success of an NPS program. The author presents possible measurements, including:

- Watershed water quality before and after implementation of BMPs;
- Program participation as measured by eligible vs. participating landowners, BMPs considered necessary vs. BMPs implemented, or dollars allocated to the NPS program vs. dollars expended; and
- Institutional goal coordination and management effectiveness.

Based upon these criteria, the voluntary NPS reduction program in Wisconsin has not succeeded in improving ambient water quality. Rector (1989) describes the evolving voluntary NPS programs nationally. The author advocates a negotiated, case-by-case agreement between the affected parties and regulators due to the unique nature of NPS discharges.

6.1.2.1 Research Needs

Possible research needs include a statistical analysis of watershed quality before and after adopting BMPs; and comparison of results nationally as well as within each state (because the program is developed along state lines).

6.1.2.2 References

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6.1.3 Determining Areas Where Regulatory Flexibility Can Achieve Watershed Goals

Milne, Dempsey, and Morris (1996) describe intermittent river dissolved oxygen standards in the United Kingdom that are frequency based for short periods of low concentration events. Bailey

(1994) outlines the results of technical committees from the scientific and regulatory community in which clear recommendations were made to use cost-effectiveness criteria in implementing CSO permits and controls. This provides for site-specific permits, allowing for technical flexibility of each permit, rather than enforcing a costly technological control. Consideration is also given to water quality standards that focus controls where they are most needed. Murray, Cave, and Bona (1996) summarize the Rouge River National Wet Weather Demonstration Project in Michigan, which allowed alternative watershed-wide permits.

Hruby (1991) examines mixing zone possibilities in New Bedford, Massachusetts, using a dye study and fitting several models including a dilution model, two estuarine flow models, and a density flow model to the data. The extent of the mixing zone depended on quantity of receiving waters; tidal currents; wind; and the density gradient between fresh water and sea water. At this location, it was found that the mixing zone concept did not achieve much regulatory flexibility, primarily because of the small amount of receiving water and the strong tidal currents.

The use attainability analysis introduced in the previous section (Novotny et al., 1997) represents an important first step in determining realistic water quality goals in urban areas.

6.1.3.1 Research Needs

Apparently, no criteria have been defined for how to evaluate regulatory flexibility, nor any clear measures of performance that can be used to evaluate the effectiveness of using regulatory flexibility. More work must be done in these two areas so the absence of adequate information does not inhibit regulatory innovation. An evaluation of performance of the use attainability analysis procedure is also needed.

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6.2 Reuse and Water Resources

As water supplies become more stressed, water conservation and reuse become more attractive options. Wastewater disposal costs also encourage more water reuse. Asano and Levine (1996) provide a historical perspective and explore current issues in wastewater reclamation, recycling, and reuse. A complete hydrologic cycle focusing on reuse can be found in Figure 6–1.

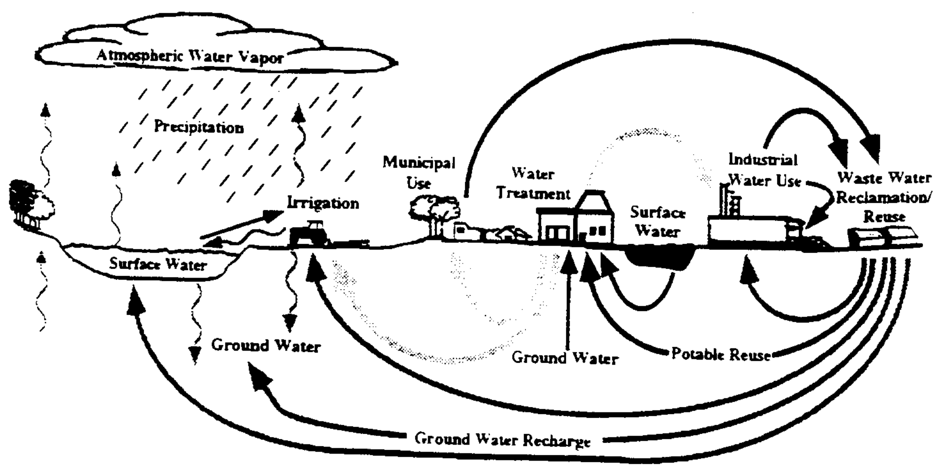

Figure 6–1. The Role of Engineered Treatment, Reclamation, and Reuse Facilities in the Cycling of Water through the Hydrologic Cycle (Asano and Levine, 1996).

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Urban wet weather flow management should be viewed within the context of overall urban water management. Such an integrated framework was proposed in the late 1960s and is regaining favor in the mid-1990s. Changes in urban water use are occurring thanks to aggressive water conservation practices which will significantly reduce indoor and outdoor water use. Based on recently collected data, per capita indoor residential water use is stable at an average of 60 gal/capita-day (Heaney et al. 1998). Aggressive hardware changes, such as low flush toilets, should reduce this usage rate to 35 to 40 gal/capita-day. Only a small proportion of this indoor waste is black water. Most of it is gray water that could be reused for lawn watering and other non-potable purposes. Peak water use in most cities is heavily influenced by urban lawn watering. This outdoor water use does not require potable quality. As the cost of water treatment continues to increase, dual water systems become more of a possibility, particularly with a decentralized infrastructure.

California has been a focal point of water reuse for some time. Ashcraft and Hoover (1991) found that reclaimed water in southern California is selling at prices ranging from $303/AF (acre-foot) to $366/AF, with costs of operation and maintenance of treatment facilities running from $10/AF to $95/AF. The authors argue that "avoided costs," such as those associated with wastewater disposal should be included in cost calculations. Requa et al. (1991) developed a wastewater reuse cost model for screening purposes in northern California. More recently, Tselentis and Alexopoulou (1996) describe a feasibility study of effluent reuse in the Athens, Greece, metropolitan area. Uses considered were: crop irrigation, irrigation of forested areas, industrial water supply, and domestic non-potable use. The most cost-effective scenario was distribution for crop irrigation near the route of the current discharge point. At the other extreme, Haarhoff and Van der Merwe (1996) describe direct potable reuse of reclaimed wastewater in Windhoek, Namibia. Law (1996) describes the Rouse Hill project in Sydney, Australia, in which a dual non-potable distribution system was installed in a new community in 1994. Oron (1996) developed an integrative economic model, arguing that the optimal cost of a reuse system is a function of: treatment method; cost of treatment; transportation and storage costs (pipelines and tanks); environmental costs; and the selling price of reused wastewater. Anderson (1996a, b) describes new initiatives for reusing stormwater flows for urban residential and industrial water supply systems in Australia. Mitchell, Mein, and McMahon (1996) used a water budget approach to integrate storage and reuse of urban stormwater and treated wastewaters for two neighborhoods in suburban Melbourne, Australia. Nelen, DeRidder, and Hartman (1996) describe the planning of a new development for about 10,000 people in Ede, Netherlands, that considers a dual water supply system. Storing the treated wastewater on-site during wet weather periods can be more attractive than reusing only black water (Pruel, 1996). Herrmann and Hase

(1996) describe rainwater utilization systems in Bavaria, Germany, that save drinking water and reduce roof run-off to the sewerage system. Imbe, Ohta, and Takano (1996) discuss the effect of urbanization on the hydrological cycle of a new development near Tokyo, Japan.

Much of this work has focused upon using treated wastewater from a single effluent plant. The problem then becomes one of locating demand centers for the wastewater, which are typically located some distance away. This becomes a nonlinear form of the transhipment problem, in which demand and distance are cost drivers in a nonlinear objective function. Many researchers have started to focus on less centralized systems, including Tchobanoglous and Angelakis (1996). Decentralized systems can take advantage of the segregation between wet weather flow, gray water, and black water, and possibly use less contaminated waters closer to their points or origin. Of the three, stormwater runoff is usually the least contaminated before central collection. This may avoid construction of additional treatment systems, pipelines, etc., and present significant cost savings. From the wet weather flow quality management perspective, there is much interest in local management of wet weather flow from smaller, more frequent events, as these events tend to have more pollutants associated with them. The primary on-site option is to encourage infiltration of this stormwater flow from roofs, driveways, parking lots, and streets. This infiltrated water increases the moisture in the unsaturated zone and raises the groundwater table which can provide benefits in terms of increasing base flows in streams and providing stormwater to help meet the evapotranspiration (ET) needs of the local vegetation.

One of the most prevalent themes advanced in the recent literature in wet weather flow management is to limit the generation of runoff from urban areas through the use of best management practices and on-site control of wet weather flow, a form of reuse, particularly in frequent small storm events (Mitchell, Mein, and McMahon, 1996). Butler and Parkinson (1997) suggest that reuse of stormwater provides a more sustainable urban drainage infrastructure by minimizing available wet weather flow that could possibly be mixed with wastewater; as well as attempting to minimize the use of expensive drinking water for irrigation. The diagram in Figure 6–2 indicates that reuse of stormwater closest to the point of generation is the highest and best use that will yield sustainable systems. Pitt et al. (1996) suggest that residential stormwater (i.e. roofs and driveways, not streets) generally has the least amount of contamination and advocate infiltration of residential stormwater as a means of disposal with few environmental impacts.

In keeping with this theme, a possible model of a residential on-site control system is shown in Figure 6–3. Precipitation falls on roofs and driveways and is channeled, with some losses, into a storage tank. The storage tank varies in size depending on the location. Water is taken from the tank for irrigation of landscape surfaces; some is used for ET, some is lost to infiltration, and some is lost to runoff. In essence, this model is an irrigation, or water deficit demand model. Irrigation demand is determined mainly from ET requirements. To calculate ET, water is budgeted daily or monthly. By examining the water balance of one residential parcel in differing climatic zones, the efficacy of the option of on-site reuse of stormwater can be evaluated across the United States. Heaney et al. (1998) performed such an analysis and found that, for many areas of the country, particularly humid ones, enough stormwater can be collected to satisfy average irrigation demands. Arid areas of the country with high ET requirements may not satisfy their irrigation demand by stormwater reuse alone; some combination of graywater and stormwater may need to be considered in these cases.

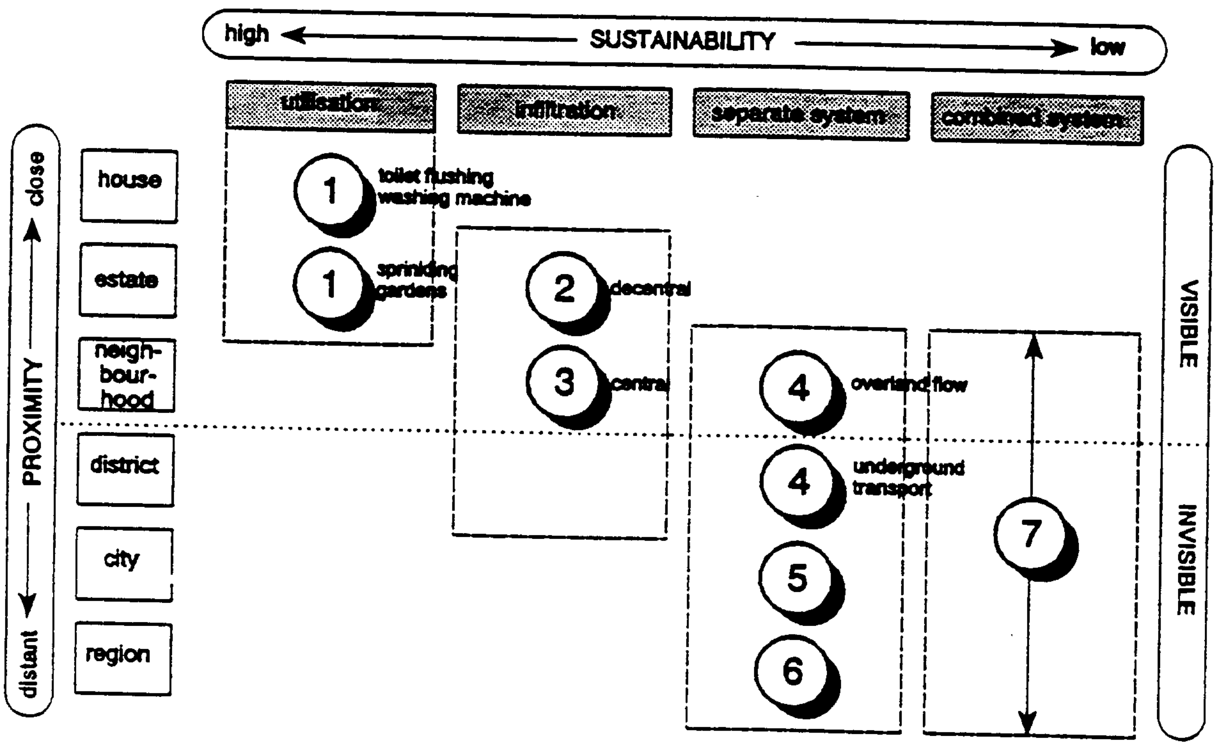

Figure 6–2. Stormwater Handling Priority Diagram, Based on Sustainability, Proximity, and Visibility (Veldkamp et al., 1997)

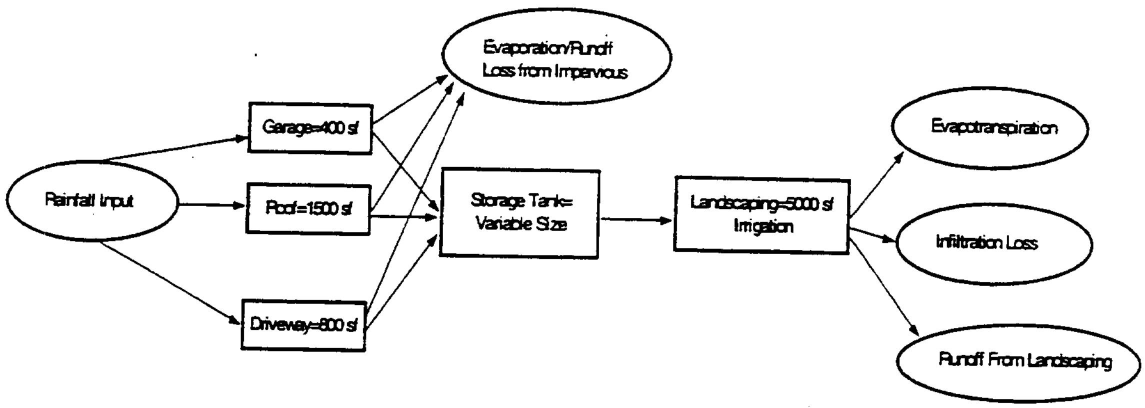

Figure 6–3. Concept of Stormwater Reuse Residential Storage System (Heaney et al., 1998)

Urban water reuse is an attractive possibility for 21st century systems. Stormwater from roofs and driveways has been shown to be of high quality and suitable for lawn watering, toilet flushing, showers, etc. Graywater from showers and baths can be used for lawn watering. Case studies of innovative systems such as the "Casa Del Agua" house in Tucson, Arizona (Foster, et al. 1988 and Karpiscak, Foster, and Schmidt (1990), the Rouse Hill Development in Australia (Law, 1996), and several in Germany (Herrmann et al. 1996) illustrate the potential of on-site water management. With aggressive on-site controls the need to import water for water supply is decreased significantly. Correspondingly, the amount of wastewater discharged off-site is also much less. Future work on both centralized and decentralized stormwater and graywater reuse systems needs to focus on economic evaluation; the area shows much promise due to the enormous amount of potential water supply available.

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6.3 Financing and Cost Analysis

Stable funding is an essential ingredient in developing and maintaining viable urban water organizations, whether they are stormwater utilities, watershed organizations, or some other organizational form. Integrated management offers the promise of improved economic efficiency and other benefits from combining multiple purposes and stakeholders. However, the benefits from integrated watershed management exacerbate problems of financing these more complex organizations, since ways must be found to assess each stakeholder's "fair share" of the cost of this operation. Nelson (1995) provides a current overview of utility financing in the water, waste-water, and stormwater areas. At least 20 states have organized their activities, in varying degrees, around watersheds (Nagle et al., 1996). For many of these state programs, nonpoint pollution control is a primary objective. These state-based watershed water quality programs are supported by reallocating existing state program monies, some of which originate from US EPA. A major gap in funding at present is the inability of the federal government to "block fund" multipurpose local agencies such as watershed organizations. Local water agencies must deal with a large number of independent federal agencies with complex requirements for obtaining financial support.

US EPA used to maintain and widely distribute information on the cost of controls. The cost estimates for the EPA Needs Surveys give helpful data, e.g., Scott et al. (1992). However, much-improved accounting and cost-reporting methods are needed to learn the true costs of various parts of wet weather management. Many urban water control facilities are multipurpose. Hence, accurate methods to properly assign costs are essential. Newer methods such as activity-based costing are helpful in this regard., but, the longer-term solution is to directly link process simulators such as SWMM with accounting systems so that costs can be properly assigned as the wet weather flow moves through and out of the urban area.

The current interest in benefit/cost analysis as part of WWF evaluations demands improved methods of estimating benefits. This has been an active research area and relatively reliable methods are now available. With proper control of WWFs, many urban receiving waters are being rejuvenated and providing a focal point for large-scale urban redevelopment.

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6.3.2 Methods of Financing

Fort Bend County, Texas, issued tax-exempt revenue bonds and impact fees to finance its drainage improvement projects (Gilligan, 1996). Urban stormwater utilities have been a successful way to fund wet weather flow pollution control systems (Benson, 1996; Reese, 1996). Roesner, Mack, and Howard (1996) describe a wet weather flow master plan that formulates an integrated way to finance necessary stormwater infrastructure for a new development near Orlando, Florida. Henkin and Mayer (1996) describe how US EPA's Environmental Financial Advisory Board (EFAB) and Environmental Financing Information Network (EFIN) can be used to create a financing strategy for implementing comprehensive conservation and management plans. One of the most promising financing alternatives for wet weather flow infrastructure needs has been the development of a stormwater utility which can assess user fees (Ferris, 1992; Reese, 1996; Benson, 1992). Debo and Reese (1995) provide a good overview of stormwater utility financing. Collins (1996) describes the formation of a county-wide stormwater utility in Sarasota, Florida. EPA used this county as its first stormwater NPDES permit in the state of Florida. Pasquel et al. (1996) describe the multifaceted funding mechanisms used by Prince William County, Virginia, to fund the county's watershed management program. The sources include a stormwater management fee based upon density and area of impervious surface and development impact fees. The authors include a detailed discussion of the major components of the fee structure. Nelson (1995) describes alternative methods for calculating system development charges for a stormwater utility.

6.3.2.1 Research Needs

Research is needed on innovative financing methods including financing urban stormwater as part of a watershed management organization.

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6.3.3 Methods of Cost Allocation

Methods of finance and revenue generation cannot simply be used alone. Costs must be allocated among users in such a way as to preserve equity; otherwise users will pursue more reasonable alternatives. McDonough and Converse (1973) examine the trade-off between pipeline and treatment costs. They propose the "added pipe rule," i.e., that a community or group that causes a new trunk pipeline to be built should pay for it. Young (1982) develops fairness criteria for an allocation method, and finds that the generally accepted separable cost, remaining benefits (SCRB) allocation model does not meet these criteria. Young postulates that, as the size of a coalition grows, the cost savings exponentially increase up to a point, then approach a constant value, decreasing the impetus toward larger and larger groups. Heaney and Dickinson (1982) use cooperative *n*-person game theory to develop the minimum costs, remaining savings (MCRS) method, which satisfies many of the criteria Young (1982) proposes (*n* is the number of participants). Ng and Heaney (1989) further explore this method further. The method uses combinations of participants to determine an equitable allocation of the project costs. A major disadvantage of the method is that the number of coalitions to evaluate is determined by the following formula: (2^n-1), and consequently expands rapidly as the number of participants grows. Lejano et al. (1992) use some of these fairness criteria in allocating costs of a water reuse project in Los Angeles.

Strus and DeWitt (1996) developed an environmental charge cost allocation model, which allocates significant environmental costs to rate-payers by use of relational database technology. The algorithm is based on an activity-based percentage of use. Heaney (1997) summarizes this literature including applications to urban stormwater management. The area of cost allocation should be expanded to include the balance between rates and system development charges.

6.3.3.1 Research Needs

Fairly assigning system costs to users requires research to link activity-based costing models to urban hydrologic simulation models such as SWMM. Another area of possible research is the use of long-term economic and financial simulation to evaluate the sustainability of urban water management.

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6.3.4 Development of Cost/Performance Data for Controls

Rudolph and Balke (1996) found that, in Zwickaw, Germany, an alternative stormwater disposal system was cheaper than connecting to the municipal storm sewer system by a factor of almost 2.5. This results primarily from connection fees due to the high costs of treating and storing urban stormwater without including social costs. Bautista and Geiger (1993) summarize the findings of a wetlands system that treats residential storm runoff before discharge into Lacamas Lake, Washington. The authors found that the system was effective at reducing sediment and nutrient loadings into the lake. Ferguson (1990) developed a monthly water balance model and applied it to 12 different infiltration basins in the Atlanta, Georgia, area. The basins differed by construction techniques and management objectives; results were reviewed in terms of costs and performance. Schmidt, Seta, and Averill (1997) describe a multi-agency pilot program for evaluation of controls in the Great Lakes area. Controls evaluated were vortex separator, a circular clarifier, a horizontal-flow plate clarifier, and an inclined rotary drum screen. Findings indicated that the vortex separator and plate clarifier achieved reductions of 50% in total suspended solids and 30% in biochemical oxygen demand (BOD), which is a possible goal of the province of Ontario. Wanielista et al. (1991) summarize research in the use of granular activated carbon (GAC) filter beds to remove trihalomethanes from an urban stormwater detention pond. Cost of treatment was approximately $4.39/1,000 gallons, annually. Li and Adams (1994) derived several analytic probabilistic models to predict from rainfall statistics the long-term performance of storage treatment devices.

Labadie et al. (1984) describe CSUDP/Sewer, and its stormwater control package, which is a model for conducting simulated real-time experiments in urban stormwater systems. The model can identify least-cost vertical layouts and sizings of storm drainage systems. The authors applied the model to identify optimal horizontal layout, which involves nonlinear programming and network flow theory; more testing on this problem is necessary.

6.3.4.1 Research Needs

Uniform information is needed on the total cost of wet weather flow controls and how to properly apportion these costs for multi-purpose projects. Information on costs and performance are typically the most difficult to get, so any new information gathered should be disseminated in the widest form available (e.g., World Wide Web).

6.3.4.2 References

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6.4 Benefits of Urban Wet Weather Flow Management

Methods for assessing the benefits of wet weather flow quantity control, in terms of reducing flood damage by providing structural and non-structural controls, are well established, e.g., James and Lee (1971), Johnson (1985). Quantifying the benefits associated with water quality improvements or the dual problem of quantifying the damages associated with water quality degradation are more difficult, but a significant body of literature represents the subject. Heaney (1994) reviews alternative environmental valuation methods and proposes property valuation as a good integrative measure of the benefits or disadvantages associated with water quality. He includes the results of case studies in Florida of lakes that have a wide variety of water quality, size, and water level fluctuation. The same approach is used on the land side to evaluate the economic impact of providing flood control and drainage. Other ways to measure the direct user benefits include recreation travel costing, and defensive expenditures to ameliorate undesirable effects. A more recent approach is to evaluate non-user benefits, e.g. the benefits a person gains from knowing that a natural resource is being protected even if this person does not use or visit this resource. Cummings and Harrison (1994) present an evaluation of non-use values. Russell (1994) describes how these benefit assessment methods can be used in the decision making process.

Contingent valuation has been successfully applied to evaluate the value to customers of improved water supply reliability. The California Urban Water Agencies conducted a contingent valuation survey of 4,000 randomly sampled customers. Customers were asked to vote on a hypothetical referendum. If the majority voted yes, monthly water bills would be increased by a specified amount and there would be no future water supply shortages. If they voted no, utility bills would remain the same but shortages would continue (Hoag, 1997). The results (Figure 6–4) indicate a willingness to pay an additional $11 to $17 per month per customer to avoid future shortages of indicated frequency and severity. These results helped assess the economic value of reliability.

George (1996) discusses the pros and cons of using benefit/cost analysis (BCA) for environmental projects. Rudolph and Balke (1996) conducted a BCA of alternative wet weather flow management systems for new residential development in the cities of Dortmund and Zwickau, Germany.

Despite these advances, quantifying benefits in urban wet weather flow management has remained a difficult task. If benefits could be determined, cost/benefit analysis could be done quite easily, as typically cost data are available. For an overview of cost/benefit analysis in water resources, see Kneese (1993). There are indirect ways of determining benefits. One of these is real estate valuation, an example of which is given in Frederick et al. (1996). The authors describe ways of making urban wet weather flow management attractive; and, if this is done, give estimates from developments in which property was made more valuable than without it (Table 6–2).

Another problem related to evaluating benefits is assessing performance. Overall watershed and ecosystem health are determined by many synergistic and related factors that cannot usually be boiled down to a single indicator that is easy to measure. This problem is illustrated in Figure 6–5 from Holmes (1996). The author is not recommending giving up the quest for a performance measure, just suggesting that it is difficult to measure performance of a management system whose goal is to protect an ever-changing environmental system in which the interrelationships are not fully understood. The measuring process is something of a moving target.

It is possible, however, to develop broad criteria of performance that can be used to focus on the weaknesses suggested by Holmes (1996). Such studies may reflect the fact that our knowledge of the problem may not sustain the high degree of resolution typically required in scientific research. Such a system was developed by AMSA (1996), which ranks performance profiles by simple subjective criteria. This study categorizes performance measures and gives advantages and disadvantages, relative cost ratings, and key attributes of each (Table 6–3). Lindsey, Swietlick, and Hall (1997), reporting on a research project for the Water Environment Research Foundation, list key stormwater quality indicators (Table 6–4). Together, these begin development of performance systems for CSO control and urban water management. However, key technical and policy issues remain. Some of these issues are (Lindsey, Swietlick, and Hall, 1997):

- What incentives can serve as the impetus for water resource managers to move to a watershed management approach? How can states and US EPA afford to move to watershed management given shrinking resources?

- Watershed management and the use of environmental indicators may be more complex than traditional source-by-source management. How do managers and their agencies overcome these new complexities?

- Is the current statutory scheme under the Clean Water Act adequate to fully deal with urban wet weather problems? If not, in what respects should it be changed?

- What are effective strategies to address the challenges posed by watersheds that cross multiple jurisdictional boundaries? What roles should different levels of government, industry, and the public play?

- How can monitoring data and BMP performance information be comparably generated, usefully accumulated, and fully shared with interested parties?

- How can wet weather data and watershed information be used at a national level for decision making and future program direction?

- How do regulators ensure accountability under a watershed approach that may rely more on performance-based results and less on end-of-pipe compliance monitoring?

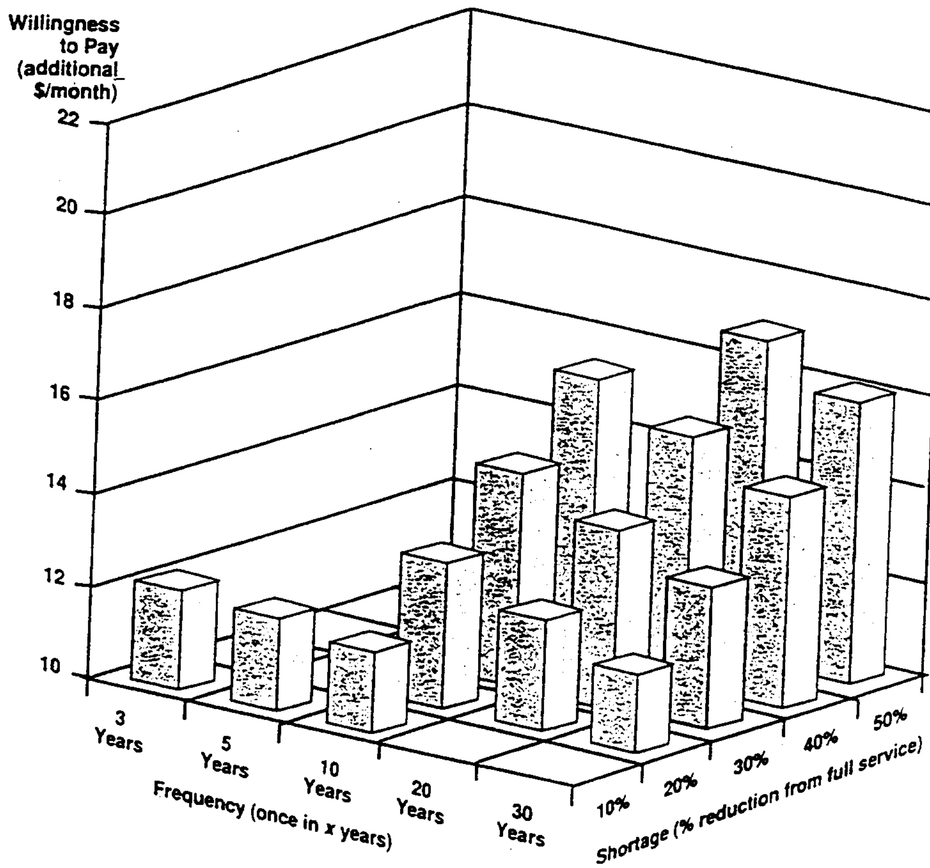

Figure 6–4. Mean Monthly Willingness to Pay to Avoid Particular Urban Water Supply Shortage Frequencies and Magnitudes (Barakat and Chamberlain Inc., 1994)

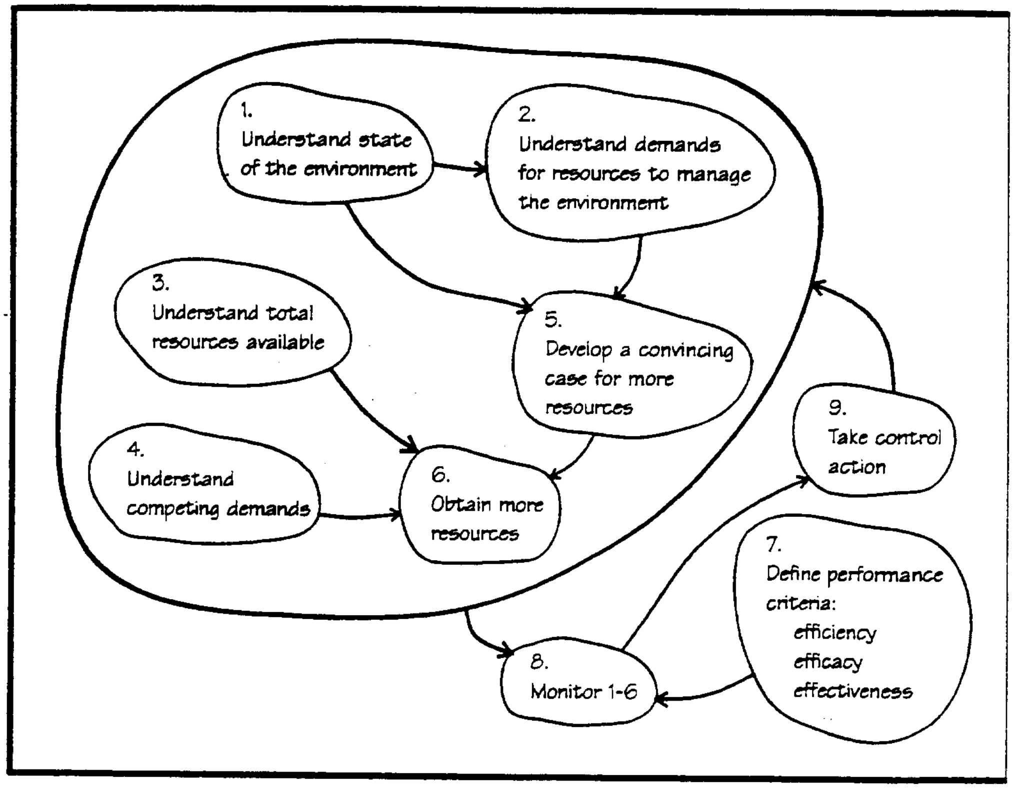

Figure 6–5. A Model of the Process of Measuring, Understanding, and Determining Possible Performance Criteria (Holmes, 1996)

6.4.1 References

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Cummings, R.G., and Harrison, G.W. (1994) The measurement and decomposition of nonuse values: A critical review. *Env. Resource Econ.* 5 (3): 225–247.

Table 6–2. Examples of Real Estate Premiums Charged for Property Fronting Urban Runoff Controls (Frederick et al., 1996)

Location	*Base Costs of Lots/Homes*	*Estimated Water Premium*
Chancery on the Lake, Alexandria, VA	Condominium: $129,990 to $139,990	Up to $7,500
Centrex Homes at Barkley, Fairfax, VA	Home with lot: $330,000 to $368,000	Up to $10,000
Townhomes at Lake Barton, Burke, VA	Townhome with lot: $130,000 to $160,000	Up to $10,000
Lake of the Woods, Orange County, VA	Varies	Up to $49,000
Dodson Homes, Layton, Fauquier County, VA	Homes with lot: $289,000-$305,000	Up to $10,000
Ashburn Village, Loudon County, VA	Varies	$7,500 to $10,000
Weston Development, Broward County, FL	Home with lot: $110,000 to $1,000,000	$6,000 to $60,000 depending on lake size, location, and the percent of lakefront property in the neighborhood
Silver Lakes Development, Broward County, FL	Varies	$200 to $400 per linear foot of waterfront, depending on lake size and view
Highland Parks, Hybernia, IL	Waterfront lot: $299,900 to $374,900	$30,000 to $37,500
Waterside Apartments, Reston, VA	Apartment rental	Up to $10/month
Village Lake Apartments, Waldorf, MD	Apartment rental	$5 to $10/month depending on apartment floor plan
Lake Arbors Towers, Mitchellville, MD	Apartment rental	$10/month
Marymount at Laurel Lakes Apartments, Laurel Lakes, MD	Apartment rental	$10/month
Lynne Lake Arms, St. Petersburg, FL	Apartment rental: $336 to 566/month	$5 to $35/month depending on lake size
Sale Lake, Boulder, CO	Waterfront lot: $134,000	Up to $35,000
The Landing, Wichita, KS	Waterfront lot: $35,000 to $40,000	Up to $20,000
Fairfax County, VA	Commercial office space rental	Up to $1/square foot
Laurel Lakes Executive Park, Laurel, MD	Commercial office space rental	$1-$1.50/square foot

Table 6–3. Summary of Recommended CSO Performance Measures (AMSA, 1996)

Administrative	*End-of-Pipe*
• Documented implementation of 9 minimum controls	**Flow Measurement**
• Status of long-term control plan*	• Wet weather flow budget
• Waste reduction	• CSO frequency*
	• CSO frequency in sensitive areas*
	• CSO volume
	• CSO volume in sensitive areas
	• Dry weather overflows
	Pollutant Load Reductions
	• BOD load
	• TSS load
	• Nutrient load
	• Floatables
Receiving Water	***Ecological/Human Health/Resource***
• Dissolved oxygen trend	• Shellfish bed closures
• Fecal coliform trend	• Benthic organism diversity
• Floatables trend	• Biological diversity index
• Sediment oxygen demand trend	• Recreational index
• Trend of metals in bottom sediments	• Beach closures
	• Commercial activities

*Appropriate for national tracking

Frederick, R., Goo, R., Corrigan, M.B., Bartow, S., and Billingsley, M. (1996) Economic benefits of urban runoff controls. *Proceedings of Watershed '96 Moving Ahead Together: Technical Conference and Exposition.* Alexandria, VA: Water Environment Federation.

George, J. (1996) Practical approaches to assessing costs and benefits: Urban erosion and sediment control as a case study. *Proceedings of Watershed '96 Moving Ahead Together: Technical Conference and Exposition.* Alexandria, VA: Water Environment Federation.

Heaney, J.P. (1994) Conceptually sound and operational methods for environmental valuation. *Water Resources Update*, Summer.

Holmes, P.R. (1996) Measuring success in water pollution control. *Water Sci. Technol.* (G.B.) **34** (12): 155–164.

Table 6–4. Stormwater Environmental Indicators (Lindsey, Swietlick, and Hall, 1997)

Water Quality Indicators:
Water quality pollutant monitoring
Toxicity testing
Nonpoint source loading
Exceedance frequencies of water quality standards
Sediment contamination
Human health criteria
Physical and Hydrological Indicators:
Stream widening/down cutting
Physical habitat monitoring
Impacted dry weather flows
Increased flooding frequency
Stream temperature monitoring
Biological Indicators:
Fish assemblage
Macroinvertebrate assemblage
Single species indicator
Composite indicators
Other biological indicators
Social indicators:
Public attitude surveys
Industrial/commercial pollution prevention
Public involvement and monitoring
User perception
Programmatic Indicators:
Number of illicit connections identified/corrected
Number of BMPs installed, inspected, and maintained
Permitting and compliance
Growth and development
Site Indicators:
BMP performance monitoring
Industrial site compliance monitoring

Hosoi, Y., Kido, Y., Nagira, H., Yoshida, H., and Bouda, Y. (1996) Analysis of water pollution and evaluation of purification measures in an urban river basin. *Water Sci. Technol.* (G.B.) **34** (12): 33–40.

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Johnson, W.K. (1985) Significance of location in computing flood damages. *J. Water Resources Plan. Mgmt.* **111**: 3–10.

Kneese, A.V. (1993) Economics and water resources—Water Resources Administration in the United States, policy, practice, and emerging issues, Reuss, M. ed., *Selected papers from the AWRA National Forum on Water. Management Policy, Washington, DC.* East Lansing, MI: Michigan State University Press.

Lindsey, A., Swietlik, W.F., and Hall, W.E. (1997) Effects of watershed development and management on aquatic ecosystems—EPA's perspective. *Effects of Watershed Development and Management on Aquatic Ecosystems, Proceedings of an Engineering Foundation Conference, Snowbird, Utah.* New York: ASCE.

Moffa, P., ed. (1990) *Control and Treatment of Combined-Sewer Overflows.* New York: Van Nostrand Reinhold.

Rudolph, K.-U., and Balke, H. (1996) Economic aspects of alternative storm water management. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hanover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage.

Russell, C.S. (1994) Evaluation of decision making in the context of environmental restoration. *Water Resources Update*, Summer.

6.4.2 Contingent Valuation

The contingent valuation method of estimating benefits uses survey information in which respondents are asked to place a value on a given environmental benefit and how much they are willing to pay for it. Rogerson (1996) explains the concept of contingent valuation and how it would apply to the water field. Crase (1996) applies contingent valuation to establish a value for wetland and woodlot areas, created as a result of a wastewater reuse project to come up with estimates of benefits for the project. Loomis (1994) uses contingent valuation to establish values for whooping crane habitat, improved water quality along the Platte River wetlands, and instream flow needs. The author also suggests how these values can be integrated into the benefit/cost framework.

Whitehead and Groothuis (1992) apply contingent valuation to the Tar-Pamlico Basin of North Carolina, and found that the benefits of improved water quality were $1.62 million each year, and based upon this finding, a survey of voters determined that they were willing to pay $1.06 million per year to achieve these improvements.

Finally, Lindsey (1992), used contingent valuation techniques to estimate the benefit of two separate wet weather flow control plans resulting in 1% and 4% nutrient loading reductions to the Chesapeake Bay. The benefits were estimated to be $1.2 million and $4.2 million, respectively. Responders preferred user charges over property taxes to pay for these reductions, but, the charging vehicle did not appear to affect their value of the reduction. Notwithstanding, the author suggests that simultaneously valuing public goods as well as evaluating the method to pay for them may not be valid.

6.4.2.1 Research Needs

Innovative methods are needed to quantify the benefits of urban water management systems. Contingent valuation has shown some promise. Significant problems remain to be solved in using this technique, and more work is necessary.

6.4.2.2 References

Crase, L. (1996) Reusing sewage water: Evaluating the benefits. *Aust. J. Environ. Mgmt.* **3** (2): vp.

Lindsey, G.H. (1992) An Experiment in Contingent Valuation: Willingness to Pay for Stormwater Management, Master's Thesis, The Johns Hopkins University, Baltimore, MD.

Loomis, J.R. (1994) The need for commensurability in values of alternative uses of water in integrated watershed management. Integrated watershed management in the South Platte Basin: Status and practical implementation. *Proceedings of the 1994 South Platte Forum*, Greeley, CO.

Rogerson, C.M. (1996) Willingness to pay for water: The international debates. *Water-S.A.* 22 (4): 373–380.

Whitehead, J.C., and Groothuis, P.A. (1992) Economic benefits of improved water quality: A case study of North Carolina's Tar–Pamlico River. *Rivers* 3 (3): 170–178.

6.4.3 CSO Measures of Success

Holmes (1996) describes the difficulty of measuring success of operation in water pollution control. In many cases, despite successful operation, other factors may cause ambient water quality may go down. There is a contradiction, however, in that the owners of treatment facilities often insist on such measures. The author suggests using quasi-biological systems as measures of effectiveness that value survival. Saget and Chebbo (1996) suggest that the following characteristics of discharges from storm sewers are important in measuring negative impacts:

- Annual loads (to determine cumulative effects);
- Loads per event (to determine acute effects over several hours); and
- Loading within events (to establish variation in small time intervals).

This work was based upon the database QASTOR, which contains both combined and separate storm sewer water quality data. Vanderkimpen, Diels, and Huberlant (1996) assess the different methods for estimation of CSO spill frequency such as:

- Spill frequency charts;
- High frequency synthetic storms;
- Composite high frequency synthetic storm; and
- Short historical rainfall series and continuous rainfall data.

The authors conclude that the spill frequency charts are relatively accurate for simple systems, but they make some assumptions that are unique for each chart and must be taken into consideration. High frequency synthetic storms may underestimate the spill frequency significantly. Composite high frequency synthetic storms correct somewhat for this, but the best method was the properly selected short historical rainfall series. Breur, van Leeuwen, and Dellaert (1996) developed a "discharge strategy" which is part of the decision model for an urban drainage system. Hedges (1994) used models for prediction of performance, and compared them with actual efficiency. In the United States, Lindsey, Swietlick, and Hall (1997) and AMSA (1996) developed broader, simpler versions of performance criteria.

6.4.3.1 Research Needs

More work in this area is needed to develop standardized measures of performance for CSO controls, particularly quantitative ones.

6.4.3.2 References

Association of Metropolitan Sewerage Agencies (AMSA) (1996) *Performance Measures for the National CSO Control Program.* Washington, DC: AMSA.

Breur, K.J., van Leeuwen, P.E.R.M., and Dellaert, N.P. (1996) Deriving discharge strategies to reduce CSO in urban drainage systems. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hanover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage.

Hedges, P.D. (1994) The prediction of combined sewer overflow performance from models—a case study. *Water Sci. Technol.* (G.B.) **29** (1–2): 373–382.

Holmes, P.R. (1996) Measuring success in water pollution control. *Water Sci. Technol.* (G.B.) **34** (12): 155–164.

Lindsey, A., Swietlik, W.F., and Hall, W.E. (1997) Effects of watershed development and management on aquatic ecosystems—EPA's perspective. *Effects of Watershed Development and Management on Aquatic Ecosystems, Proceedings of an Engineering Foundation Conference, Snowbird, Utah.* New York: ASCE.

Saget, A., and Chebbo, G. (1996) QASTOR: The French database about the quality of wet weather urban discharges. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hanover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage.

Vanderkimpen, P., Diels, F., and Huberlant, B. (1996) CSO impact assessment and engineer's point of view. *Proceedings of the 7th International Conference on Urban Storm Drainage*, Hanover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage.

6.5 Education and Outreach

Education is an important nonstructural BMP component of an urban wet weather flow management plan, both in terms of the general public, and municipal, state, and federal professionals. The latter group is particularly important when there is an increasing burden on municipal government in terms of regulatory compliance, at a time of decreasing funding, and possibly mixed political commitments on the local level. US EPA has, in certain cases, required an educational component of a municipal stormwater discharge permit as a nonstructural BMP (Pitt et al., 1997). According to Urbonas (1998), the point of public education is to modify behavior, but the he finds that little is known about the effectiveness of such programs.

Schumacher and Grimes (1992) describe the public education program developed as part of the Charlotte, North Carolina wet weather flow planning process. This program consists of:

- Inform the public about regulatory requirements; and
- Formally involve special interest groups in the wet weather flow management process.

General guidance on education and outreach can be found in Beech and Dake (1992) and US EPA (1993). Fujita (1993) describes an extensive education program in Tokyo, Japan, to explain the new Experimental Sewer System (ESS). This education program convinced the public of the advantages of infiltration in reducing local flooding and restoring desirable groundwater conditions. The state of Illinois has prepared several education booklets to explain the watershed management program to the public (Water Environment and Technology, 1996).

Current studies in Austin, Texas, are the first to explicitly link investments in public education with improvements in receiving water quality (Pitt et al., 1997). While this link will probably remain difficult to establish directly, public education is an essential component of urban wet weather flow management.

A number of local public education programs for cities abating wet weather flow pollution were sponsored by US EPA (Austin, Latrou, and Rheams, 1996; Feuka, 1996). A multi-media public information campaign was an important part of efforts to achieve a 40% reduction of nutrients entering Chesapeake Bay (Leffler and Flagle, 1996).

Two important key areas of research are public involvement and participation techniques and coordination of research across agencies. A more detailed analysis of these areas follows.

6.5.1 References

Austin, G., Latrou, A., and Rheams, A. (1996) Art and fun help save Lake Pontchartrain. *WEF Urban Wet Weather Pollution: Controlling Sewer Overflows and storm water Runoff.* Alexandria, VA: Water Environment Federation.

Beech, R.M., and Dake, A.F. (1992) *Designing an Effective Communication Program: A Blueprint for Success.* Chicago, IL: University of Michigan, School of Natural Resources and Environment, for the US EPA Region 5.

Feuka, K.P. (1996) Public education for private inflow removal in the cities of Portland and Westbrook, ME: A US EPA demonstration project. *J. New England Water Enviro. Assn.* **30** (1): 27.

Fujita, S. (1993) Infiltration in congested urban areas of Tokyo. *Proceedings of the 6th International Conference on Urban Storm Drainage.* Victoria, BC, Canada: International Association of Water Quality.

Leffler, M., and Flagle, R. (1996) Backyard actions for a cleaner Chesapeake Bay: A cooperative outreach program. *Proceedings of Watershed '96 Moving Ahead Together: Technical Conference and Exposition.* Alexandria, VA: Water Environment Federation.

Pitt, R., Lilburn, M., Nix, S., Durrans, S., and Burian, S. (1997) *Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanizing Areas (New WWF Systems).* Interim First Year Progress Report to US EPA, Edison, NJ.

Schumacher, J.W., and Grimes, R.F. (1992) A model public education process for storm water management. *Public Works* **123** (9): 55–58.

Urbonas, B. (1998) BMP effectiveness. Chapter 6 in Heaney, J.P., Wright, L., and Sample, D., eds. *Development of Methodologies for the Design of Integrated Wet-Weather Flow Collection/Control/Treatment Systems for Newly Urbanizing Areas,* US EPA, draft report, Edison, NJ.

US EPA (1993) *Handbook, Urban Runoff Pollution Prevention and Control Planning.* Office of Research and Development, EPA/625/R-93/004.

Water Environment and Technology (1996) *Illinois Turns to Communities for Grassroots Watershed Work.*

6.5.2 Public Involvement, Participation Techniques

Lange (1991) suggests identifying important stakeholders most interested in decision making in river corridor planning, as well as developing an information and education program. The author also stresses that the planning effort should have a "clear vision" and should focus on budgetary concerns for implementation.

Terranova and Tice (1995) describe the public involvement in the NEPA analysis done for several towns in Illinois devastated by the 1993 Midwest floods; an environmental review of alternatives is required by NEPA and FEMA before construction. The process was an attempt to: 1) maximize public involvement, while maintaining a fast track toward environmental assessment (EA) adoption, through on-site and telephone interviews, 2) educate the public on the NEPA process, 3) prepare a site-specific summary of the draft EA for the community to review, 4) notify the public about pending meetings and deadlines, and 5) facilitate a public forum prior to finalization of the EA. In application, it was found that attempting to facilitate more public involvement earlier in the process would better assist local decision making that became protracted as a result of delays in public awareness of the issues.

Nazarenus (1995) describes the sometimes difficult process of increasing citizen involvement, first laying out several basic rules, including using layman's terms instead of technical ones, and discussing the project with those directly involved to attempt to increase their "ownership" of the project. Techniques the author used include: open houses, professional technical assistance, training sessions, marketing techniques, and better customer support.

Stiftel (1990) evaluates the North Carolina NPS pollution control program (see Section 6.1.2) and found significant disagreement between staff interpretations of public support and public survey results. The author suggests that this is caused by the undue influence of private interests, as well as inherent bias and tendency toward categorization. Stiftel also found that there are, with qualification, significant subgroups within the general population; however, the vast majority tended to be moderate on development and environmental issues. Marcy and Gerritsen (1996) describe the active, diverse citizen involvement in managing the Chesapeake Bay ecosystem.

6.5.2.1 Research Needs

Methods should be developed to evaluate the efficacy of public involvement and participation techniques. Case studies could be included.

6.5.2.2 References

Lange, D. A. (1991) Public involvement in multiobjective river corridor planning. *Proceedings of the Urban Stream Corridor and storm water Management Workshop and the Multi-Objective Management of River Corridors and Their Restoration.*

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Nazarenus, D. (1995) Winning friends. From the mountains to the sea—developing local capability. *Proceedings of the Nineteenth Annual Conference of the Association of State Floodplain Managers.*

Stiftel, B. (1990) Balance of representation in water planning: An assessment of experience from North Carolina. *Environ. Plan. B: Plan. Design* 17: 105–120.

Terranova, A., and Tice, C. (1995) A public involvement strategy developed for the FEMA Midwest Hazard Mitigation Program. *Proceedings of the Nineteenth Annual Conference of the Association of State Floodplain Managers.*

6.5.3 Coordination of Wet Weather Flow Research Across Agencies

Simonovic and Bender (1996) describe a collaborative planning-support system (CPSS) which, by integrating models and databases from different areas in a user-friendly environment, enhances the iterative planning process by enhancing the communication between disciplines. Sherman (1995) advocates the need for inter-agency coordination to develop cost effective solutions to environmental degradation caused by wet weather flow management. Scott (1996) provides a literature review of wet weather flow research across Australia to assist in interagency coordination and avoid duplication.

Lesouef (1996) discusses water management institutions and the concepts of centralization versus decentralization; the author found that significant cultural and political context, geography, water surplus or shortage, and the necessity of a dynamic equilibrium were factors which influenced the degree of centralization chosen by the institution. Korf, Wilken, and Nel (1996) describe the formation of a wastewater management company in the East Rand of South Africa. They compare this model with other management organizations, including agencies, private companies, metropolitan boards, local governments, central governments, mix of public and private entities, and river basin management organizations.

6.5.3.1 Research Needs

Comparative studies of U.S. practices versus programs in other countries would be helpful. Countries such as Great Britain and Australia are conducting multi-purpose watershed research. It would be useful to compare coordination of research within this context. A collaborative effort with the public administration field in this area may be beneficial.

6.5.3.2 References

Lesouef, A. (1996) Institutions and water management efficiency: The art of equilibrium. *Water Sci. Technol.* (G.B.) **34** (12): 91–100.

Korf, A.W., Wilken, J.W., and Nel, N.J. (1996) Strategies and management models for metropolitan waste water, implementation and evaluation in the East Rand, South Africa. *Water Sci. Technol.* (G.B.) **34** (12): 101–108.

Scott, A. (1996) Review of urban storm water research in Australia. *Tech. Mem. CSIRO Div. Water Resour.* **96**: 9.

Sherman, M. (1995) Developing partnerships to address storm water management issues. *Land-Water* **39**: 45–47.

Simonovic, S.P., and Bender, M.J. (1996) Collaborative planning-support system: An approach for determining evaluation criteria. *J. Hydrol.* 177 (3/4): 237–251.

CHAPTER 7.0

CONTROL TECHNOLOGIES

Table 2–8 presents a master list of 67 research needs that involve control technologies to reduce wet weather impacts. These may be grouped into three general categories:

- Source control at the land-parcel or street-side level, e.g. on-site storm management and grass-lined swales;
- Collection system innovations, e.g. sewer rehabilitation; and
- Treatment and storage technologies, e.g., end-of-pipe, high-rate treatment systems.

Some of these technologies have been used in the field of urban wet weather management for some time but may be described as evolving because they are not widely used and are not fully understood at a process level; others may be more aptly described as being in their infancy. Recent work has focused on the integration of the urban water cycle (of which urban drainage is a component) with land use planning under the guiding principle of creating a more sustainable urban environment (Butler and Parkinson, 1997).

7.1 On-Site Control

Of the 67 control-oriented research needs listed in Table 2–8, 14 were identified as dealing primarily with on-site control. Section 7.1.2 covers two topics from Table 2–8, swales and swales instead of curbs. Section 7.1.3 covers three topics from Table 2–8, reduction of directly impervious surfaces, modification of urban surfaces to reduce hydraulic and pollutant loads, and performance of porous and permeable pavements. Two other, more generic, sections, toxic source reduction and improved source reduction are included in the section on modifying urban land-surfaces, but also involve many other research. Chapter 3.0 and Section 3.2 specifically cover characterization of toxic sources. Research needs associated with source reduction first require characterization of pollutants. However, the concept of pollutants associated with urban surfaces is generic, and research needs presented in Section 7.1.3 are indirectly relevant to toxic-source reduction. This section presents one-page summaries of nine on-site controls, and further research needed to improve their performance. The organization of research needs topics is shown in Table 7–1.

Control of urban wet weather impacts has traditionally been achieved through public drainage works; typically capturing urban runoff after it leaves privately owned lands. Drainage works on private lands are designed to collect runoff and transport it from urban land parcels to public drainage works as efficiently as possible. This "minor" drainage system typically provides drainage for events with recurrence intervals of 2 to 10 years (Table 7–2) and provides relief from nuisance flooding (ASCE/WEF, 1992). "Major" drainage ways are natural or improved channels that convey runoff that exceeds the capacity of the minor system, including emergency outfall facilities (ASCE/WEF, 1992). The level of service expected from conventional urban drainage works is shown in Table 7–2. The technologies described in this section are primarily concerned with modifications of the way parcel-level drainage interacts with the minor drainage system, and how the minor-drainage system operates. Therefore, on-site control technologies are designed to affect frequent storm runoff events: those with return periods shorter than 0.5 years. Candaras, Carvalho, and Koo (1995) refer to this category as micro-storm management.

With regard to urban runoff quality, traditional urban drainage works have exacerbated certain deleterious impacts of imperviousness: for example, nonpoint source (NPS) pollution accumulates on impervious surfaces and is transported via surface runoff directly to receiving waters (Schueler, 1995; ASCE/WEF, 1992). Impervious surfaces increase storm runoff volume and the peak flow rate and decrease the time-to-peak flow, effectively decreasing the level of service provided by stormwater infrastructure investment. In addition, a valuable resource has been "wasted" in areas where outdoor water use is a major component of the urban water cycle.

The impact of the automobile on urban runoff quality has been an especially important aspect of urban land use over the past 50 years. Imperviousness may be seen as a function of road width and lot density. Schueler (1995) highlights the importance of land-use planning in terms of pervious or impervious surfaces for urban NPS reduction.

Table 7–1. On-Site Control Research Needs (Unprioritized)

Section	*Table 2–8 ID#*	*Research Topic*
7.1 On-Site Controls		
7.1.2 Swales	88	Effectiveness of swales
	96	Swales instead of curbs
7.1.3 Modifying urban surfaces	151	Reduce directly connected impervious area
	90	Modifying urban surfaces to reduce hydraulic and pollutant loads
	109	Performance of porous and permeable pavements
	94	Improved methods of source reduction
	93	Toxics sources reduction
7.1.4 Reduce I/I from laterals	152	Reduce I/I in house service laterals
7.1.5 Design improvements for micro-storms	91	Urban drainage design improvements for micro-storms
7.1.6 Stormwater reuse	95	Stormwater reuse
7.1.7 Storm inlet devices	97	Storm inlet device
7.1.8 Industrial runoff control	98	Industrial runoff control
7.1.9 Reuse of runoff as cooling water	89	Reuse of urban runoff as cooling water
7.1.10 Roadway and airport deicing	99	Roadway/airport deicing

Table 7–2. Design Storm Frequencies for Minor and Macro Drainage Systems (ASCE/WEF, 1992)

Land Use	*Design Storm Return Period*
Residential	2 to 5 years
High value commercial	2 to 10 years
Airports (terminals, roads, aprons)	2 to 10 years
High value downtown business areas	5 to 10 years
Major Drainage System Elements	50 to 500 years

As a result of the impacts of impervious surfaces on runoff quality, wet weather researchers have investigated various means of reducing stormwater runoff and associated NPS pollution at the urban-parcel level. Researchers are attempting to implement broadly defined societal goals such as "sustainability" along with traditional goals of public health and safety and environmental protection. For example, recent work in Henze et al. (1997) and Sieker and Verworn (1996, 1997) highlight the problems associated with accounting for the future external costs of urbanization. The time scales relevant to the sustainability of urban drainage works are shown in Figure 7–1. Along with unforeseen scenarios, the difficulty in developing truly sustainable systems seems to lie in the uncertainty associated with forecasting the nature of the future urban environment within which the drainage infrastructure must operate.

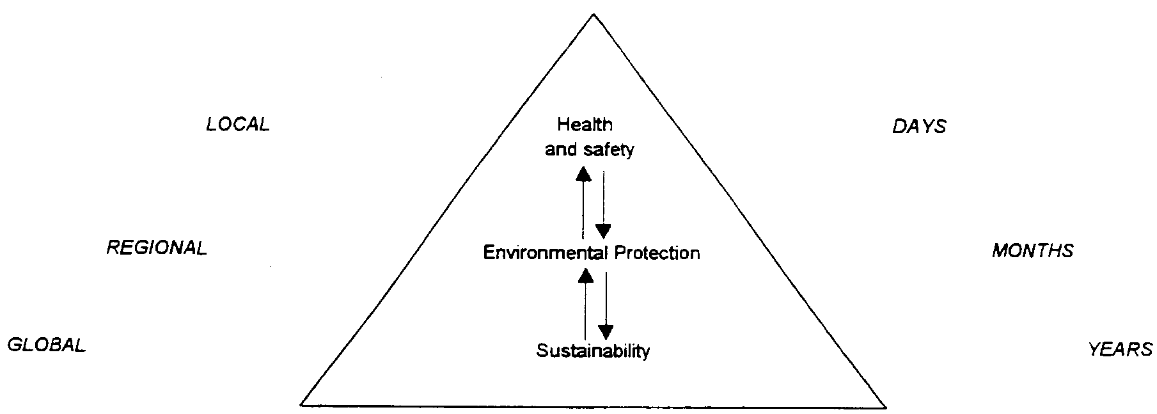

Figure 7–1. Hierarchy of Objectives of Drainage Systems Showing Increasing Extent of Spatial and Temporal Effects (Butler and Parkinson, 1997)

Larsen and Gujier (1997) describe the essential dilemma created by drainage works in dense urban land use:

> Urban drainage is fundamental for preventing flooding of many urban areas. Although urban drainage has serious consequences for the water cycle and for the quality of receiving waters during storm events, it is not possible to maintain present population densities without this service. In many urban areas a continuous draining of groundwater is necessary.

Urban drainage is therefore a necessary service for a rapidly urbanizing world. If we are to reduce long-term costs of urbanization and move toward sustainability, urban drainage works should move toward the following goals (Nelen, de Ridder, and Hartman, 1996):

- Control at the source;
- Control of the source;
- Minimization of flows;
- Use of sustainable materials; and
- Minimization of energy and other resources.

Figure 7–2 presents a conceptualization of these goals. On-site control strategies such as stormwater utilization (e.g., stormwater reuse) score high on the sustainability axis because reuse does not require the transportation of "wastes," and does not mix stormwater with that of other origins. The goals of on-site technologies may be summarized as follows (adapted from Pitt et al. 1997; Butler and Parkinson, 1997; Larsen and Gujer, 1997):

- Utilize stormwater as a resource;
- Minimize NPS pollution loads on a frequent-storm basis;
- Minimize quantity of runoff to better control flooding;
- Better satisfy short-term societal goals of public health and safety;

- Adhere to societal goals of minimized environmental impact; and

- Move toward satisfying long-term societal goals, such as sustainability.

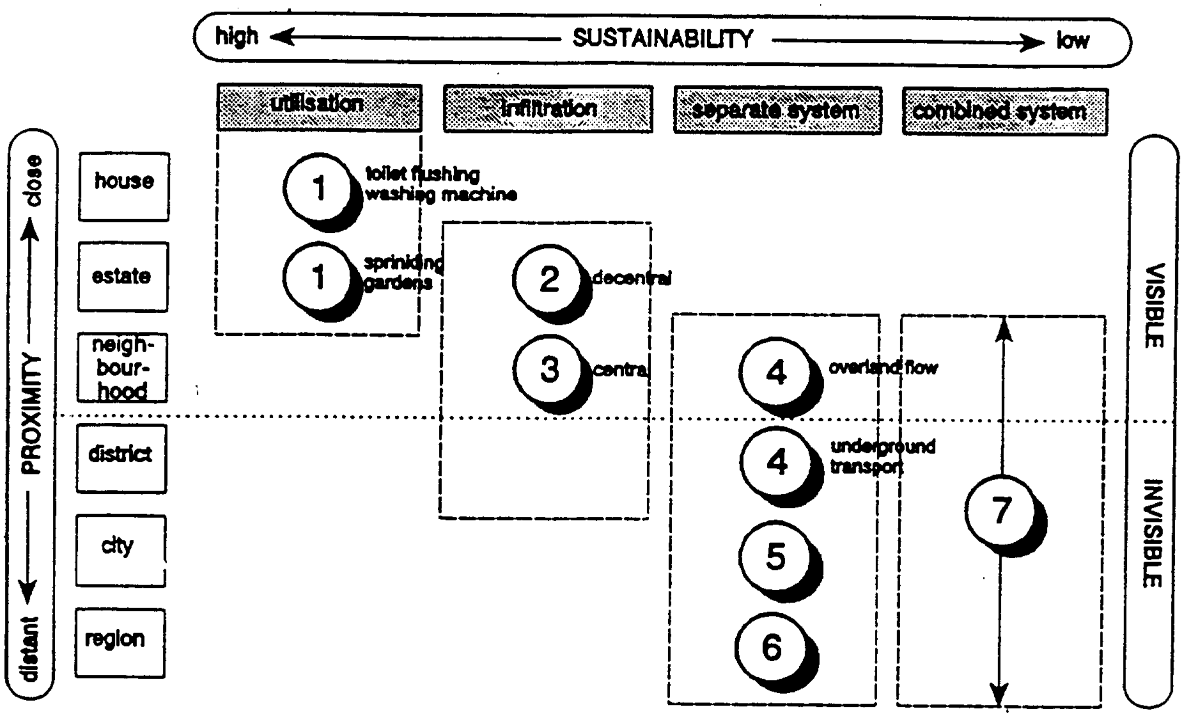

Figure 7–2. Stormwater Handling Priority Diagram, Based on Sustainability, Proximity, and Visibility (Veldkamp, Hermann, and Colandini, 1997)

7.1.1 References

American Society of Civil Engineers (ASCE)/Water Environment Federation (WEF) (1992) *Design and Construction of Urban Stormwater Management Systems*. ASCE Manuals and Reports of Engineering Practice No.77, WEF Manual of Practice FD-20. New York: American Society of Civil Engineers.

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Candaras, A.M., Carvalho, L.M.J., and Koo, M.K. (1995) City of Etobicoke exfiltration and filtration systems pilot/demonstration project. James, W., ed., *Modern Methods for Modelling the Management of Stormwater Impacts*. Guelph, ON: Computational Hydraulics International.

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7.1.2 Swales

Grassy swales have been recommended as a best management practice (BMP) in urban runoff control for some time, particularly for runoff from highways. Urbonas, Roesner, and Guo (1996) define a grassy swale as a component of a runoff treatment system that holds stormwater from one event until displaced by the next. Yousef et al. (1985) found that for highway runoff flowing over swales, ionic components of heavy metals and nutrients were reduced; possibly by "sorption, infiltration, precipitation, co-precipitation, and biological uptake." Urbonas (1997) documents the current literature on grassy swales as a BMP. Current research is consistent with past findings; namely that there is a significant removal of pollutants (e.g. from 20 to 40% removal of total suspended solids). Urbonas (1997) suggests that grass swales are most appropriate in areas where slopes are less than 3 to 4%, which tends to lower flow velocities. Even better performance is achieved in soils with very high infiltration rates. This indicates that infiltration is the essential removal mechanism, and, due to this characteristic, grassy swales may reduce the runoff volume as well as the runoff peak in certain cases. Pitt et al. (1997) also document the current literature on the use of swales and include reviews on studies of the potential for groundwater contamination from infiltration. The authors indicate that groundwater contamination is not a major concern for the majority of urban areas. Livingston (1993) reports on work from Florida in which equations were developed to aid in the design of swales to achieve a given level of performance.

Livingston (1993) provides a good first step in the development of quantitative analysis of swales. Pitt and Voorhees (1997) summarize the application of the source loading and management model (SLAMM) which, based on a simplifying method using the statistical characteristics of small storm hydrology, enables a user during planning to assess the performance of a variety of controls, including swales. A computer model of a grassy swale/perforated pipe urban runoff treatment system was developed by Paul Wisner & Associates (1994).

7.1.2.1 Research Needs

There seems to be more quantitative analysis for the performance of wet detention ponds than for grassy swales. More work should be done in this direction so that the mechanisms of pollutant removal in swales are better understood and swales can then be integrated into stormwater treatment systems.

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7.1.3 Modifying Urban Surfaces to Reduce Hydraulic and Pollutant Loads

The impervious nature of urban surfaces is a well-documented problem associated with urban drainage (Schueler, 1995). Modification of these surfaces to improve runoff quality and reduce runoff volume and peak flow is an attractive land-use modification that has shown promise in several applications around the world. Two major forms of urban surface modification are:

increasing pavement porosity, and reducing directly connected impervious areas. Porous and permeable pavement has been developed in three forms: porous asphalt, porous concrete, and permeable modular locking concrete blocks with open cells (Urbonas and Stahre, 1993; Pratt, 1997). Of the three, modular blocks show the most promise, because this form does not clog as quickly as porous asphalt or concrete, and is easier to clean and maintain (Urbonas and Stahre, 1993). Kresin, James, and Elrick (1997) report decreased infiltration capacity of porous pavement with age. There has been concern in the United States regarding the ability of porous and permeable pavements to withstand freeze–thaw cycles (Urbonas and Stahre, 1993). However, Pratt (1997) recently cited work in Sweden and the United Kingdom that indicates that porous pavement performance exceeds that of impermeable pavement. In the United States, Florida has been a leader in the use of porous pavement; 90,000 m^2 of the pavement were constructed by 1990 (Ferguson, 1994). In Tokyo, Japan, it is estimated that 494,000 m^2 of both porous and permeable pavement have been constructed since 1984 (Pratt, 1997). Reduction of directly connected impervious surfaces in an urban catchment involves hydraulically breaking the connection of impervious surfaces and the minor or local drainage works (Urbonas and Stahre, 1993). For example, retrofitting existing roof drainage downspouts is a common example of disconnecting impervious surfaces (Urbonas and Stahre, 1993). New development may use more advanced techniques, such as porous driveways and roof drainage to landscaped ground or to onsite reuse facilities. Problems with draining impervious areas to pervious land include boggy mosquito-breeding areas, poor snow removal, and hazardous roadside ditches (Urbonas, 1997). If infiltrated water has drained from impervious surfaces that are sources of NPS pollution groundwater contamination may be a concern (Pitt et al., 1996).

7.1.3.1 Research Needs

Quantitative, long-term assessment of these BMPs is greatly needed. Effects of enhanced infiltration on the urban water budget including groundwater and runoff quality must be measured. Fundamental physical processes of infiltration through porous or permeable pavements remain poorly understood. Cooperation with experimental research in Canada and Europe would be helpful.

7.1.3.2 References

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7.1.4 Reduce Inflow and Infiltration in House Service Laterals

Infiltration and inflow (I/I) represent a large portion of the nation's treated wastewater. Nation-wide estimates of annual I/I volume are as high as 50% of total wastewater flow (Petroff, 1996). Houston, Texas, has reported peak to average ratios of sanitary wastewater flow as high as 50:1 (Jeng, Bagstad, and Chang, 1996). I/I can cause sanitary sewer overflows (SSOs), with sewer system surcharging typically occurring as peaking ratios reach 4:1 or 5:1 (US EPA, 1990). Traditional I/I reduction strategies employ remedial actions on the sewer collection system. However, privately owned house laterals may introduce as much as much as 70 to 80% of the total infiltration in a sanitary sewer (Field and O'Connor, 1997). Elliot et al. (1997a, b) report that private sources contribute more than 60% of I/I in Lower Paxton Township, Pennsylvania. This poses significant problems for the owner of an aging sewer system. Expensive field monitoring is needed to isolate leaking laterals. Flow monitoring in conjunction with video inspection is typically used. Gokhale, Kaufmann, and Stein (1997) describe new techniques of testing water tightness in existing buried pipes using low-pressure air tests. Air is pumped into the sewer, and the rate at which inflow air is required to keep the pipe at constant pressure is measured (Gokhale, Kaufmann, and Stein, 1997). While there is no known fundamental relationship between the rate that air leaks out of a pipe and water leaks in, there is a direct correlation: sewers that leak more water in, leak more air out (Gokhale, Kaufmann, and Stein, 1997). This technology may prove economically feasible as test cases are performed and the technology develops.

7.1.4.1 Research Needs

The problem of service laterals leaking extraneous flow into sewers is a problem of economics: the shear number of privately owned laterals prevents rehabilitation on a scale large enough to effect a change in wet weather flows. Monitoring technologies noted above may prove important in identifying deficient laterals; however the problem of the number of laterals, each with an independent owner, remains. Therefore, this research problem lies largely in the area of sewer system administration. Building code enforcement, billing strategies, and incentives for private owners to fix deficient laterals must be investigated. As monitoring and control of sewers becomes standard practice for other reasons, an indirect benefit may be the ability of a sewer owner to monitor leaks at the parcel level. Future sewer billing strategies may include a charge for the volume of service rendered, similar to what is done in the water supply field. Research conducted in this area should be closely linked with research in sewer monitoring and control, and with institutional changes in sewer administration.

7.1.4.2 References

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7.1.5 Urban Drainage Design Improvements for Micro-Storms

The concept of design improvements for micro-storms is that, by concentrating on these more easily controlled events, the first flush of pollutants into the urban drainage system can be eliminated. Candaras, Carvalho, and Koo (1995) studied the performance of an exfiltration/filtration system and determined that it was successful at meeting the goal of micro-storm elimination. O'Loughlin, Beecham, and Goyen (1996) emphasize the need for research into smaller storms and smaller catchments to avoid overdesign. Because of the wide spatial and temporal variation in runoff, storms of short duration are defined with measurement intervals of one minute or less, using pluviograph records for more than 10 years. In the absence of this type of data, extrapolations of intensity–duration–frequency (IDF) curves are made. Another method was developed by Pitt and Voorhees (1993), who attempted to reduce the data requirements by statistical techniques, noting the similarities in the rainfall-runoff interrelationships for different urban areas. This technique is the basis for the source loading and management model (SLAMM)), which was later extended in Pitt et al. (1997).

7.1.5.1 Research Needs

Candaras, Carvalho, and Koo (1995) describe the need to develop physically-based algorithms, methods, and computer models to facilitate the application of the BMPs in the Etobicoke study so that their use can be easily extrapolated to other areas. More research must be done in terms of the data requirements and statistical properties of small and micro storm hydrology; possibly in the area of aggregation/disaggregation analysis before model development. As O'Loughlin, Beecham, and Goyen (1996) indicate, extrapolations of IDF curves from known storms to smaller events typically results in overestimation of the smaller event, and subsequent overdesign of facilities.

7.1.5.2 References

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7.1.6 Stormwater Reuse

This option is defined as the direct reuse of stormwater for beneficial uses, as opposed to a disposal option in which no value is obtained from the resource. Mitchell, Mein, and McMahon (1996) developed an urban water balance model to determine the effect of stormwater and wastewater reuse and suggested its application at a number of scales. They determined that water demand from reservoirs in Australia could be halved through the use of this resource. Herrmann et al. (1996) found that rainwater usage (using roof runoff water directed into a storage tank) could provide 30 to 50% of total water consumed in a residence, and reduce heavy metals (in stormwater runoff not reused) by 5 to 25%. Wanielista (1993) developed design curves to determine the storage retention volumes necessary to achieve given proportions of reuse. The design curves are based on a daily water-balance model. The main objectives for this practice in the State of Florida are the costs avoided of using municipal or pumped groundwater for irrigation; from the regulatory viewpoint, the main objectives are to discharge some of the stormwater onto the land and thereby get credit for 100% removal of this pollutant source. Field (1993) studied cost-effectiveness of the reuse of urban stormwater to meet a variety of differing demands for a hypothetical urban area. The proposed uses varied in their water quality needs, as did the corresponding treatment system designated for that use. Nowakowska-Blaszczyzyk and Zakrzewski (1996) project increases in suspended solids, nitrates, COD, BOD, and lead from rainfall routed through the following sources: roofing, parking areas, streets, storm sewers, infiltration through lawns, and infiltration through sand. The lowest values tended to be from roof runoff. Karpiscak, Foster, and Schmidt (1990) detail the application of stormwater and gray water reuse techniques at a single residence in Tucson, Arizona.

7.1.6.1 Research Needs

The effectiveness of stormwater reuse should be evaluated at a variety of scales and for a variety of climates, in terms of both cost and environmental efficacy. Information is needed on sizing on-site stormwater cisterns to capture the runoff and reuse it on-site for irrigation , toilet flushing, and other non-potable purposes. The expansion of experimental houses, such as Casa del Agua, to other climates and expanding these monitoring efforts to include evapotranspiration and water storage in the vadose zone is important. Other open questions are any possible measurable or modeled impacts on the urban wet weather system. The possible segregation of stormwater into roof runoff, driveways, residential streets, arterial streets, commercial or industrial site runoff and its possible use as a resource must be evaluated.

7.1.6.2 References

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7.1.7 Storm Inlet Devices

Stormwater inlet devices are designed to intercept and convey surface runoff to closed conduit storm sewers (ASCE/WEF, 1992). The hydraulic capacity of an inlet is a designed feature that depends on the geometry of the structure (ASCE/WEF, 1992). Generally part of the "minor" drainage works described in Section 7.1, inlet devices are an important structural feature of the sewer. An extension of this concept of micro-storm management, as discussed in Section 7.1.5 includes inlet devices to promote rooftop and on-site storage (Urbonas and Stahre, 1993). As indicated by Urbonas and Stahre (1993), control devices used to promote storage tend to be maintenance-intensive and may promote nuisance flooding if not properly designed and maintained. As the entry point to the storm sewer, inlet devices play a role in treatment and control. As a hydraulic control point, inlet structures may be designed to statically control flow via grate geometry, pipe inlet control (such as weir, hydraulic brake, orifice, etc.); or as a dynamic control point as part of a control system (manual or automatic-real-time) using devices such as inflatable dams, motor-controlled gates (Field, 1996). Standard catch basins were monitored for solids capture effectiveness in Bellevue, Washington, and found to capture the largest portion of street solids (Pitt et al., 1997). Stormwater treatment devices may be added to inlet design to capture solids. Sumps added to the bottom of catch basins have been used in the United Kingdom and were also found to capture the largest-diameter fraction of solids in stormwater. Inlet devices using filter fabric to screen solids have been demonstrated in Stafford Township, New Jersey (Pitt et al., 1997). Significant solids and COD reductions were found (up to 50%); however, the filter medium tends to clog rapidly (Pitt et al., 1997).

7.1.7.1 Research Needs

Pitt et al. (1997) cite recent research that indicates that traditional catch-basin performance is fairly well understood. Modifications of the basic design (sumps, self-cleaning trash racks, etc.) have been demonstrated. Use of flow control devices in inlet structures is also a well-understood. Issues to be resolved regarding inlet structures pertain to the overall vision of future urban drainage works. What level of control and treatment is needed at the micro, minor, and major drainage system levels? The maintenance cost of catch basins is a major concern. As treatment is decentralized, maintenance becomes a problem. At the micro-level, rooftop storage by downspout inlet control is generally not a practical solution because the maintenance requirements become a burden to private owners (Urbonas and Stahre, 1993). In fact, Urbonas and Stahre (1993) report that rooftop inlet control devices have a tendency to disappear over time as they clog and create maintenance problems for the owners. Therefore, while performance data may not be a high-priority research item, the role that the inlet device may play in an integrated drainage system may be important.

7.1.7.2 References

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7.1.8 Industrial Runoff Control

Precipitation that falls on industrial sites is usually of the same water quality as precipitation that falls on residential sites. However, the working practices of a particular industry and site may cause runoff to become contaminated by contact with various pollutants such as oils, greases, pesticides, heavy metals, suspended solids, as well as BOD from the overland flow surface of the site. According to Field (1993), thousands of toxicant laden stormwater discharges emanate from industrial sites. Hubbard and Sample (1988) describe a method of tracing toxicants in storm sewers to individual industrial sites. They used downstream water quality, stormwater system plans, land use information identifying the type of industry in each parcel in the area, and chemical analyses of the sediments in the storm drains.

Moffa (1996) develops a generic case study of an industrial site discharging stormwater to a small creek. The company becomes subject to NPDES regulation, selects a consultant, and begins a program of monitoring to establish dry weather baseline water quantity and quality near the discharge to the creek. Stormwater management model (SWMM) studies are performed to establish what pollutants may exceed regulatory standards at established frequencies of storm events. When a pollutant exceeds the regulatory criteria, the model is rerun with selected control or BMP options and consequent expected source reductions; this is repeated until the criteria are met. Weiss (1993) provides a concise summary of US EPA's permitting strategy, an overview of the regulations, options for treatment and control as well as minimization of contaminated stormwater. Due to the complex industry, and location-specific nature of the problem, US EPA's strategy is to tailor each permit to site-specific conditions (Weiss, 1993).

7.1.8.1 Research Needs

According to Field (1993), no research has been done in the area of assessment and control of industrial stormwater runoff. The mandate for regulatory compliance gives particular emphasis to this need. Claytor and Brown (1996) describe preliminary research on environmental indicators that may attest the effectiveness of industrial stormwater control programs. The US EPA industrial stormwater permitting program, due to its site-specific nature, will gather much information, including treatment and control options, type of industry, and so forth. As these data are collected, it would be possible to develop a database of this information, combine it with local site-specific information from available GIS databases, and develop performance evaluations of industry-specific control strategies.

7.1.8.2 References

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7.1.9 Reuse of Urban Runoff as Cooling Water

Field (1993) determined, in a cost-effectiveness comparison, that cooling water reuse of treated stormwater ranks second only to irrigation, primarily due to the cost of meeting a higher water quality standard for cooling water purposes. This is especially important in that, according to Field and Fan (1981), cooling water is a substantial component of the estimated 53.5 billion gallons of water consumed per year. Ferguson (1987) discusses "harvesting" of urban stormwater for cooling water purposes, and gives site-specific formulas for the application of this technique.

7.1.9.1 Research Needs

Despite the cost-effectiveness of the reuse of urban runoff for cooling water purposes, there does not seem to be a large body of research in this field. More detailed treatability studies and pilot testing should be performed to determine whether this option is feasible. Industrial users may be employing this technique to control industrial runoff to avoid discharging it in accordance with an NPDES permit. If this is the case, then appropriate studies could be done across categories of industries employing this technique to determine the most efficient treatment, reuse, and management processes.

7.1.9.2 References

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7.1.10 Roadway and Airport Deicing

Field and O'Shea (1992) document the problem of salt- and sand-laden stormwater runoff from roadways. The authors find the annual cost of damages resulting from this runoff to be $5.4 billion dollars. Research into alternatives to the use of salt as a deicing agent include hydrophobic pavements and highway coating methods. Lord (1988) summarizes an $8 million research effort into alternative deicing chemicals, reduced chemical usage, improved operation practice (including storage), pavement heating, pavement modification, and mechanical approaches. The author notes that promising research efforts include ice–pavement bond prevention and destruction, improved displacement plows, control of blowing snow, and management.

Madden (1995) details the current treatment options for airport deicing fluids (glycol) and associated stormwater. The options include disposal to an off-site or on-site wastewater treatment plant, on-site anaerobic treatment and disposal, and on- or off-site processing for reuse. The economics of the high cost of deicing chemicals and the large quantities used favor reuse. Alternative chemicals to glycol include urea, calcium and magnesium acetate, potassium acetate, and sodium formate.

7.1.10.1 Research Needs

Many of the research projects Lord (1988) mentions have come to fruition as many cities use alternative deicing chemicals to assist in the removal of snow and ice. Improved all season and specialized traction tires have also been introduced. Alternative chemicals come at an increased cost, however, primarily because sodium chloride is relatively inexpensive. Environmental education may be necessary to inform the public of the benefits of using more environmentally acceptable alternatives.

Airport deicing has become highly technologically sophisticated because it is typically subject to NPDES permitting. State-of-the-art recycling and treatment systems are the norm, particularly for new airports; however, even these systems are not fail-safe. The high cost of deicing chemicals used in airports creates a direct economic incentive to maximize the reuse of these compounds.

7.1.10.2 References

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7.2 Collection Systems

Collection systems are an integral part of wet weather urban water management. Sanitary sewers as well as combined sewers and storm sewers provide drainage in some fashion; by draining groundwater via inflow and infiltration (I/I) in sanitary systems, or by providing designed drainage in combined and storm sewers. Research in the area of collection systems continues to be an area of interest, especially in Europe and Japan (Henze et al., 1997; Sieker and Verworn, 1996; Ashley, 1996; Bally et al., 1996). Practical experience from research in the United States is most active in the area of integrating technological advances and fundamental research findings into practice, as

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evinced by recent WEF technical conferences (WEF 1994a, b, 1995a, b, 1996) and a recent US EPA seminar (US EPA, 1996). Innovative researchers are rethinking the role of urban drainage from the ground up, as seen in recent research involving on-site drainage practices and the concept of micro-storm management (see section 7.1) (Candaras, Carvalho, and Koo, 1995)

Problems associated with collection systems during wet weather continue to be costly. Excessive I/I, sanitary sewer overflows (SSOs), and combined sewer overflows (CSOs) are common collection system problems in the United States. These problems are rooted in deteriorating infrastructure and past design practices based on rules of thumb to account for complex system functions (e.g. solids transport) and did not take into account modern system demands and performance standards.

I/I continues to be a costly problem. While rehabilitation costs, especially those requiring excavation, are costly, a fundamental problem is that of privately owned laterals. The expense of rehabilitating private sources of I/I can be as high as the treatment and conveyance costs of I/I. Current work on I/I is presented in Section 7.2.8. and shows that I/I control will be an area of research that will include technological innovations (e.g. trenchless technology) as well as administrative changes in the way private sources are handled. Field and O'Connor (1997) show that I/I rehabilitation for SO control may be more expensive than high-rate treatment technologies more commonly used for CSOs. This offers more evidence that engineered solutions to collection system problems should be viewed from the life-cycle cost perspective and that alternatives should be selected from a wide range of available technologies. Operation and maintenance (O&M) is an important area of collection system performance. Maintenance is a costly and necessary function system owners must provide to achieve acceptable performance. The effectiveness of preventive maintenance is an important research area for the near future, as the present infrastructure ages. Advances have been shown (see Section 7.2.9) in implementing data management in preventive maintenance scheduling; however, careful examination of the life-cycle costs of new rehabilitation techniques is needed.

Earlier research on infiltration focused on estimating the natural infiltration associated with rainfall runoff processes. The conventional wisdom was that the infiltration rate decreased over time during the storm event as the soil grew wetter and absorbed less moisture. In recent years, attention has shifted to using infiltration as an important on-site control. Infiltration can be induced by providing areas that are more porous, grading the land to encourage infiltration, and directing runoff from impervious to pervious areas. Increased attention to correctly depicting infiltration in urban areas revealed the gaps in our knowledge. No longer could infiltration be dealt with simply as a loss term in the water budget. Key gaps are listed below:

- Incorporating the effect of irrigation on infiltration rates. Existing continuous simulation models ignore the important impact of irrigation on antecedent conditions for wet weather models. Existing models simply assume that the antecedent conditions depend solely on the time since the previous storm event. In reality, lawns and gardens are watered frequently during the growing season. Thus, the antecedent conditions tend to be quite wet. The soil moisture budget for urban areas is fairly complex during the growing season because irrigation systems vary widely in terms of practices, e.g., automatic sprinklers vs. "hose-draggers," the ways in which these sprinklers are operated, etc. (Courtney, 1997).

- Estimating the effectiveness of run-on systems. Stormwater from impervious areas is directed to pervious areas for infiltration and perhaps later use as a source of evapotranspiration for plants.

- Correctly accounting for the fate of infiltrated water. Detailed on-site monitoring is needed to determine the final fate of infiltrated water. Does it go to deep percolation? Is it used by the local plants for evapotranspirative needs? Does it provide base flows for local receiving waters? Does it infiltrate into sewers?

- Accurately predicting infiltration for disturbed soils found in urban areas. For example, Pitt et al. (1997) cite the results of field sampling of infiltration rates in Oconomowoc, Wisconsin, vary widely in actual infiltration rates. They do not always decrease over time. Therefore, on-site monitoring is essential.

A corollary to a better understanding of infiltration is the general question of the effect of stormwater infiltration on groundwater quantity and quality. This topic is discussed in Chapter 3.0.

A major concern of system owners is the cost of operation. The traditional means of securing construction contracts has shown significant weakness in terms of costs over the project life of the sewer. The least expensive construction costs may result in increased operation and maintenance costs. Research into the administration of the life-cycle costs of sewers is needed to prevent unnecessary expenditures on rehabilitation. Institutional and legal changes are needed if progress is to be made in this area.

The behavior of solids in sewers is fundamentally linked to overflows, O&M costs, system performance, and treatability of wastes, especially for high rate treatment. The fate and transport of solids in sewers also has implications for design as well as operation and performance. The use of common design rules-of-thumb (e.g., ill-defined minimum velocities and grades) to ensure transport of solids has led to significant operational problems. Excess sedimentation in sewers may cause clogging and promote hydrogen sulfide production, both resulting in operational problems that affect the lifespan and performance of the sewer (Schafer, 1994). Research in Europe (Ashley, 1996; Ackers et al., 1996) shows that common design standards may not be enough, given the highly variable nature of solids load. Recent work on the behavior of solids in sewers is presented in Section 7.2.3.

New approaches for the design and operation of combined sewers to control sediment problems were presented by Blaszczyk and Ashley (1996). A 10-year, $331 million CSO sewer separation project was recently completed by the cities of St. Paul, South St. Paul, and Minneapolis. A total of 189 miles of storm sewers and 11.9 miles of sanitary sewers were installed, 168 miles of oiled streets were paved, and roof leaders at 21,900 residential properties were disconnected.

Further work is needed in several areas to improve collection system performance and to take advantage of recent technological advances. Other research needs discussed in this section are more fundamental in nature, and knowledge gained may be applied to many different types of sewers, i.e. solids behavior in sewers may be germane to sanitary, combined and storm drainage collection systems. Other needs, Such as section 7.2.4 "Use of Simulation Models in Storm Sewer Design," are system-specific. Another group of research needs relates to the application of computer technology. Innovations related to the computer information revolution are still being investigated and will require significant research resources in the future. For instance, data management capabilities are now greater than envisioned when most of the systems in use today were designed. Adapting design practices to take advantage of computer capabilities in system operation are critical. Data collection will be crucial to the properly designed collection system of the future.

Real-time control (RTC) of collection systems is an active area of research in Europe and Canada. Automatic control schemes to maximize in-line storage have been successful in many collection systems in the United States as well as in Canada and Europe (Vitasovic and Zhou, 1997; Schilling, 1996). While the United States has a 30-year history of using RTC, Canada and Europe are using more advanced control permitted by their more aggressive development and implementation of these methods during the past decade. RTC in the United States began in 1967 when demonstration projects were used for CSO control in Cleveland, Detroit, Minneapolis, and Seattle. These projects attempted to use RTC to increase collection system storage. U.S. cities that are either using or studying RTC systems include Cincinnati, Cleveland (Hudson, 1996), Detroit, Milwaukee, Lima (Cantrell et al., 1996), Philadelphia (Day, 1996), Rochester, and Seattle (Chantrill, 1990). This area shows significant promise, especially for large systems that have complex responses to wet weather conditions.

Future collection systems will be viewed more as an integral part of the urban hydrologic cycle. As such, fundamental knowledge gained in sediment transport and behavior will have a direct influence on modeling and design techniques, which in turn will play a role in system monitoring and operational control. These functions will be operated in the context of the urban water budget, which includes water use and distribution, indoor and outdoor use, water conservation, climate, receiving water quality, and beneficial uses. In addition, improved water management practices will be developed through integration with other urban systems, such as transportation and land-use planning.

In summary, this section covers areas of collection system research that will ensure that future design and operation of collection systems will be more efficient and more integrated with the management of the total urban water budget. Research areas cover fundamental physical knowledge such as sediment behavior, technological advances involving computer data management and modeling, and operational efficiency such as optimized preventive maintenance practices.

Of the 67 research needs identified in Table 2–8, twelve concern collection systems. Two needs from Table 2–8 are for better operation and maintenance of collection systems; these are covered together in Section 7.2.7. Two others concern solids handling—sewer flushing and solids disposal; these are covered together in Section 7.2.8. Two needs are associated with collection system design—design practices and innovative design; these are covered together in Section 7.2.10. The needs are grouped in Table 7–3.

7.2.1 References

Ackers, J., Butler, D., John, S., and May, R. (1996) Self-cleansing sewer design: The CIRIA procedure. *Proceedings of the 7th International Conference on Urban Storm Drainage, Hannover, Germany.* IAHR/IAWQ Joint Committee Urban Storm Drainage.

Table 7–3. Research Needs Identified for Collection Systems (Unprioritized)

Section	*Table 2–8 ID #*	*Research Topic*
7.2 Collection Systems		
7.2.2 Instrumentation and monitoring	100	Instrumentation & monitoring to evaluate sewer hydraulics
7.2.3 Deposition and scour in sewers	101	Laboratory & field studies of deposition & scour in sewers
7.2.4 Use of simulation models	102	Use of simulation models in storm sewer design
7.2.5 Rehabilitation of sewers	104	Cost-effective ways to rehabilitate & replace old sewers
7.2.6 Improved I/I control	153	Improved I/I control in sanitary and storm sewers
	129	Cross-connection identification
7.2.7 Sewer maintenance effectiveness	106	Sewer maintenance effectiveness
	154	Sewer maintenance optimization
7.2.8 Sewer and sediment tank flushing	107	Sewer and tank sediment. flushing
	110	Sludge/solids disposal aspects of control options
7.2.9 Innovative design of sewers	105	Sanitary sewer system design practices
	108	Innovative design of sanitary and storm sewers

Ashley, R., ed. (1996) Solids in sewers. *Water Sci. Technol.* (G.B.) **33**: 9.

Bally, D., Assano, T., Bhamidimarri, R., Chin, K.K., Grabow, W.O.K., Hall, E.R., Ohgaki, S., Orhon, D., Milburn, A., Purdon, C.D, and Nagle, P.T., eds. (1996) Water Quality International '96, Pt. 2. *Water Sci. Technol.* (G.B.) **34**: 3–4.

Blaszczyk, P., and Ashley, R.M. (1996) Application of new criteria to control sediment problems in combined sewers in Poland. *Water Sci. Technol.* (G.B.) **33** (9): 245–252.

Candaras, A.M., Carvalho, L.M.J., and Koo, M.K. (1995) City of Etobicoke exfiltration and filtration systems pilot/demonstration project. James, W., ed., *Modern Methods for Modelling the Management of Stormwater Impacts.* Guelph, ON: Computational Hydraulics International.

Cantrell, C.J., Godsey, A., Schnipke, D., and Frutchey, R. (1996) Analysis of the city of Lima real time control system utilizing a state of the art hydraulics computer model. *Proceedings—Urban Wet Weather Pollution*. Alexandria, VA: Water Environment Federation.

Chantrill, C. (1990) Real time control of combined sewers: A U.S. view. Torno, H.C. ed., *Urban Stormwater Quality Enhancement*. New York: American Society of Civil Engineers.

Courtney, B. (1997) An Integrated Approach to Urban Irrigation: The Role of Shading, Scheduling, and Directly Connected Imperviousness. Master's Thesis, Department of Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder.

Day, T.J. (1996) Real-time control in CSO: Maximizing flow with automation. *Proceedings—Urban Wet Weather Pollution*. Alexandria, VA: Water Environment Federation.

Field, R., and O'Connor, T. (1997) Control strategy for storm generated sanitary sewer overflows. *J. Environ. Eng.* **123** (1): 41–46.

Henze, M., Somlyody, L., Schilling, W., and Tyson, J., eds. (1997) Sustainable sanitation. *Water Sci. Technol.* (G.B.) **35**: 3.

Hudson, D.M. (1996) Protecting the waters of Lake Erie through real time control of CSOs in the Cleveland area. *Proceedings—Urban Wet Weather Pollution.* Alexandria, VA: Water Environment Federation.

Pitt, R., Lilburn, M., Nix, S., Durrans, R., and Burian, S. (1997) *Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanizing Areas (New WWF Systems)*, interim first year progress report to US EPA, Edison, NJ.

Schafer, P.L. (1994) Two feet per second ain't even close. *WEFTEC '94: Collection Systems and Residuals & Biosolids Management, Proceedings of the Water Environment Federation 67th Annual Conference. and Exposition*. Alexandria, VA: Water Environment Federation.

Schilling, W. (1996) Potential and limitations of real-time control. *Proceedings 7th International Conference on Urban Storm Drainage*, Hannover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage.

Sieker, F. and Verworn, H. R., eds. (1996) *Proceedings 7th International Conference on Urban Storm Drainage*, Hannover, Germany, IAHR/IAWQ Joint Committee Urban Storm Drainage, volumes I, II, and III.

Water Environment Federation (1994a) *A Global Perspective for Reducing CSOs: Balancing Technologies, Costs, and Water Quality*. WEF Specialty Conference Series Proceedings, Louisville, Kentucky. Alexandria, VA: WEF.

Water Environment Federation (1994b) *WEFTEC '94 Proceedings of the Water Environment Federation 67th Annual Conference and Exposition*, Chicago, Illinois, part 1: Collection Systems, volume III. Alexandria, VA.: WEF

Water Environment Federation (1995a) *Sewers of the Future*, WEF Specialty Conference Series Proceedings, Houston, Texas. Alexandria, VA: WEF.

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Vitasovic, Z.C., and Zhou, S. (1997) Dynamics and Control of Urban Drainage Systems. Unpublished working paper.

7.2.2 Instrumentation and Monitoring to Evaluate Sewer Hydraulics

The complications of measuring flow in gravity sewers have frustrated sewer designers and operators since sewer measurements were first attempted in efforts to evaluate sewer hydraulics. The situation is complicated by the amount of solids and debris flow, sewer surcharging that results in pressure flow, highly variable flow rates, and limited physical accessibility. Primary measurement devices are the most reliable means of flow measurement, but are difficult to retrofit into existing sewers and may require significant maintenance. Most sewers were designed and constructed before the value of flow data was realized in sewer operation, and therefore do not have the appurtenances required for permanent monitoring. Many sewer owners resort to using temporary or semi-permanent velocity and depth measurements, usually in conjunction with a data logger. Measurement difficulties can be traced to problems associated with velocity measurements over the cross section of the conduit.

Monitoring technology has advanced along with the computer/information age. Digital data are recorded and efficiently transferred to databases for use in analysis. The problems associated with flow measurement, however, are more fundamental because the problems are physical in nature. Velocity sensor technology is advanced, but the problems noted above confound accurate measurement. Modern velocity sensor technologies include Doppler sensors (which rely on the change in frequency of sound waves reflected from suspended solids), electromagnetic sensors (which use the Farraday principle of current generated by a conductor flowing through a magnetic field), and transit time sensors (which rely on acoustic transmission across the width of the conduit). All of these have applications in which they excel, however all may be subject to relative error when used in actual sewers. Recent innovations include use of an array of Doppler sensors to better estimate mean velocity in large sewer pipes (Erb, Vander Heyden, and Kyser, 1994; Hughes et al., 1996). Accuracy was improved from ±20% for a single Doppler sensor to ±7.4% for an array of Doppler sensors (Hughes et al., 1996).

7.2.2.1 Research Needs

The research needs associated with monitoring and instrumentation are twofold: improving the characterization of velocity with reliable, low maintenance sensors; and developing design criteria for in-system monitoring stations to be included in all new designs. Research should focus on improving the relationship between measured (point or chordal) and estimated average velocity for all flow depths. Notwithstanding, over the long-term, higher priority should be given to developing design criteria for in-system monitoring stations. This will advance the evolution of collection systems to coincide with advances in data management, control, and simulation.

7.2.2.2 References

Erb, H.G., Vander Heyden, W.H., and Kyser, M.D. (1994) Flow measurements in combined rain-pool sewers in Germany. *A Global Perspective for Reducing CSOs: Balancing Technologies, Costs, and Water Quality*. Alexandria, VA: Water Environment Federation.

Hughes, A.W., Longair, I.M., Ashley, R.M., and Kirby, K. (1996) Using an array of ultrasonic velocity transducers to improve the accuracy of large sewer mean velocity measurements. *Water Sci Technol.* (G.B.) **33** (1): 1–12.

7.2.3 Laboratory and Field Studies of Deposition and Scour in Sewers

Characteristics of sewer solids are critical to wet weather pollutant transport and treatment in sewer collection systems. Sewer solids are typically characterized by settling velocity, size distribution, and concentration. Solids exhibit a wide range of variability in all of these measures, in addition to site-specificity. For these reasons, characterization of sewer solids by laboratory and field studies is crucial for complete analysis of the performance of sewers and treatment works, and receiving water impacts. Settling velocity is the most important physical property to measure because it determines the gravitational effects on the solids load, aiding in scour and deposition analysis and treatability. Pisano (1996) describes two methods of settleability tests: the method most widely used involves a large mechanically mixed settling column with sample extraction ports along the longitudinal axis; in the other method, developed in Germany, settleable solids are separated and then placed in an Imhoff cone with one outlet at the bottom. The former method is expensive and produces data with considerable "noise," while the latter method does not take into account non-settleable floatables and uses a much smaller (i.e., less representative) sample (Pisano, 1996). Aiguier et al. (1996) compare these two methods with a third method used in France that involves two tests, one for particles of less than 50 mm and one for particles of 50 mm and greater. The authors concluded that the German method always produces higher settling velocity results because of the extraction of the non-settleable portion of the solids (Aiguier et al., 1996).

In addition to the testing methods, there are also two methods of collecting solids samples from sewers. The most straightforward is to simply collect a sample of the flow; the method used more widely in Europe uses solids scraped from the wall of the sewer (Pisano, 1996). While the first method may appear to be the most representative, many hidden problems are inherent in that this method is very sensitive to the manner in which the sample is collected. Automatic samplers and hand pumps shear solids and may not produce enough intake velocity to collect heavier solids. Grab sampling techniques are effective but highly variable, and representative samples from the bottom of large diameter sewers are difficult to capture. Conversely, the scraping method is simple and inexpensive, but only captures solids that have already deposited, therefore the sample may not be representative.

7.2.3.1 Research Needs

Research is needed to determine proper equipment and procedures to conduct settleability tests in a uniform manner. Currently, a wide variety of data is collected, but the wide variation in techniques prevents comparison of information gleaned from them. Important design and operation questions can only be answered if solids data are comparable. This would greatly increase the applicability of design data across systems, e.g., the design experience of one sewer could more effectively be applied to design of another. Systematic solids measurement would also greatly aid modeling and transport studies, providing fundamental information on the physics of solids in sewers.

7.2.3.2 References

Aiguier, E., Chebbo, G., Bertrand-Krajewski, J.L., Hedges, P., and Tyack, N. (1996) Methods for determining the settling velocity profiles of solids in storm sewage. *Water Sci. Technol.* (G.B.) **33** (9): 117–125.

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7.2.4 Use of Simulation Models in Storm Sewer Design

The use of mathematical models to simulate sewer performance for design and operation is common practice for major projects. However, for many of these projects, the simulator is used merely to mimic performance under design storm conditions. The limits of design storm simulation to represent life-cycle performance over a wide range of conditions is well documented (Davis, Moffa, and Dent, 1993; Nix, 1994, 1996; Heaney and Wright, 1997). Continuous, long-term simulation of the integrated wet weather environment (e.g. runoff surfaces, micro/minor/ major drainage works, storage/treatment facilities) is advantageous in that overall performance is measured over a wide range of real events (Nix, 1994). Models that can interface well with relational databases and time series information that represents system inputs and outputs over the simulation period are advantageous. In addition, models that interface easily with other programs, e.g. optimization routines, are advantageous in that they allow designers to change key parameters and measure the potential impact of the change. Unfortunately, the most widely used non-proprietary simulation package in the United States, the US EPA SWMM, does not easily facilitate database–GIS–optimization interfacing, although it does perform continuous simulation.

Models that do perform needed functions and take advantage of modern interfacing capabilities are proprietary. Based on experience with SWMM, public domain software is valuable if it can be trusted. Also, private interests may add value and usability to the software and resell it because software source codes are available in the public domain.

7.2.4.1 Research Needs

Efforts should focus on making continuous simulation a common design practice via integration with time series databases. The public sector has a vested interest in maintaining a usable, modern modeling framework that private vendors can work from to produce value-added packages. The simulation program of the future will ideally be integrated within a "tool-box" of decision and design software. This will allow design performance to be more accurately measured by making full use of available databases and decision support software. The model evolution should include: full use of 32-bit PC-based architecture, object-oriented programming to facilitate project specific integration, and available executable code for extensive modification and additions by users and private software companies.

7.2.4.2 References

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Heaney, J.P., and Wright, L.T. (1997) On Integrating continuous simulation and statistical methods for evaluating urban stormwater systems. James, W., ed., *Advances in Modeling the Management of Stormwater Impacts*. Guelph, ON: Computational Hydraulics International.

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Moffa, P.E. ed. (1996) *The Control and Treatment of Industrial and Municipal Stormwater*. New York: Van Nostrand Reinhold.

7.2.5 Cost-Effective Ways to Rehabilitate and Replace Old Sewers

Aging sewers are prone to collapse, to clog, and to allow excessive inflow and infiltration (I/I). Approximately 600,000 miles of combined and sanitary sewers exist in the United States, and each 1,000 miles of sewer sustains approximately 50 major main breaks per year (WEF, 1994). As the sewer infrastructure ages, it will require extensive rehabilitation to maintain a desirable level of service. Unfortunately, if the rehabilitation requires digging and replacing, the costs of rehabilitation are very high, which leads to a less than satisfactory level of service and high O&M costs. Therefore incentive is strong to rehabilitate sewers without digging. Recent work in trenchless technology appears promising, and advances in this area are expected to continue. Current state-of-the-art trenchless technologies (Najafi, Varma, and Stutterheim, 1997) include :

- Cured-in-place pipe;
- Sliplining;
- In-line replacement;
- Close-fit pipe;
- Point source repair; and
- Sewer manhole replacement.

Larsen et al. (1997) presents comparative costs for some of these technologies in South Florida. They found costs for rehabilitation of a 300-foot sanitary sewer section to be:

- Chemical grouting, $3,000 (only for leaking joints);
- Fold and formed liner, $12,200;
- Cured in-place liner, $14,300;
- Slip lining, $21,000 (reduces hydraulic capacity);
- Pipe bursting, $24,000; and
- Full replacement, $30,000

In addition to the costs of the various technologies and the trade-offs for each, the local traffic and neighborhood disturbances may be more important than the sewer repair costs. This is especially true in urban areas where a high density of commerce may be critical for local businesses.

7.2.5.1 Research Needs

Research should evaluate laboratory and case study experience on trenchless rehabilitation technologies. While construction costs have been documented, long-term maintenance costs are not as available because these methods are relatively new. Long-term performance also must be measured for different sewer types, locations, etc. An impartial review of available technologies is needed that considers total life-cycle costs. Demonstration projects may be a useful tool, providing a controlled means of measuring performance and costs. In addition, as collection system monitoring and control technologies advance, rehabilitation may include construction of additional sewer appurtenances to accommodate data collection. The costs of not doing this during rehabilitation projects may prove to be costly over the extended life-cycle of the sewer. A new WERF research project will be underway in spring, 1998 entitled Innovative Materials and Techniques for New and Replacement Sewers.

7.2.5.2 References

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Water Environment Federation/American Society of Civil Engineers (1994) *Existing Sewer Evaluation & Rehabilitation*. WEF MOP FD-6, Alexandria, VA: Water Environment Federation. ASCE No. 62., New York: American Society of Civil Engineers.

7.2.6 Improved Inflow and Infiltration Control in Sanitary and Storm Sewers

Inflow and infiltration (I/I) is a costly and widespread problem in the United States. Petroff (1996) estimates that 50% of treated wastewater in the United States is derived from I/I. Besides increasing treatment and pumping costs, I/I is a major cause of sanitary sewer overflows. A review of 10 case studies indicates that peak wastewater flows ranged from 3.5 to 20 times the average dry weather flow (DWF) (US EPA, 1990). Maximum ratios have been reported as high as 50:1 in Houston, Texas (Jeng, Bagstad, and Chang, 1996). The US EPA (1996) estimates that 27% of SO occurrences result from excessive I/I. Costs of I/I may also be found in the design and construction of sewers. Designs must include allowances for future I/I, thus increasing construction costs. Heaney et al. (1997) estimate that the majority of sewer capacity currently in use in the United States is intended to accommodate extraneous flows.

While inflow is commonly lumped together with infiltration, the two are derived from different sources and result from different deficiencies in the collection system. Direct inflow sources commonly result from illicit connections, from unenforced building codes or absent inflow-related requirements, or from poorly designed or maintained interaction with the surface drainage system (e.g. flooded manhole covers resulting from poor street drainage). Infiltration, on the other hand, commonly results from deteriorating sewer infrastructure. This is complicated by the fact that much of the infiltrated volume may be from private sources such as privately owned, small diameter, service laterals. Elliot et al. (1997a, b) estimate that 42% of I/I in a central Pennsylvania community comes from private laterals during a peak I/I event. Elliot et al. (1997a, b) estimate the costs of I/I removal for the community. Rehabilitation costs range from $0.40 to $.36/gal. removed for sump pump removal and grouting manholes and sewer line, to $.20 to $3.72/gal. for lateral repairs. By comparison the conveyance and treatment cost for each gallon of I/I is estimated to be $3.81 to $18.80/gal.

7.2.6.1 Research Needs

Research related to I/I control should follow several paths. First, there is a need to examine feasible means of controlling inflow via proper sewer administration. Second, there is a need to develop design criteria for the sewer of the future that will include life-cycle costing, data monitoring, and infrastructure design compatible with the needs of the future. I/I control should play a major role in rethinking sewer infrastructure. Third, there is a need to demonstrate the life-cycle cost-effectiveness of current rehabilitation technology.

7.2.6.2 References

Elliot, J.C., Hydro, S.K., Malarich, M.A., and Weaver, W.R. (1997a) Private infiltration/inflow source removal to achieve high level flow reductions. *Collection Systems Rehabilitation and O&M: Solving Today's Problems and Meeting Tomorrow's Needs, Conference Proceedings*, Kansas City, Missouri. Alexandria, VA: Water Environment Federation.

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7.2.7 Sewer Maintenance Effectiveness

Maintenance of collection systems plays a major role in the overall performance of the system and usually contributes much of the life-cycle costs. As such it is critical to effective administration of maintenance operations. Innovative municipal owners are using computer databases and GIS systems to manage sewer maintenance operations. The city of Garland, Texas, a suburb of Dallas–Fort Worth, has integrated historical maintenance information with current GIS mapping to administer O&M (Hardin and Messer, 1997). Age of sewer, number of complaints, number of overflows, and preventive maintenance are recorded in a database and used to develop routine maintenance schedules. For example, problem sewer lines are scheduled for line cleaning every 0.8 years, while non-problem lines are scheduled for cleaning every 10 years. In this way, areas that have been problematic in the past are identified and scheduled for preventive maintenance. The city of San Diego, California, is using GIS and decision analysis software to set priorities for preventative maintenance and rehabilitation projects with the overall goal of reducing SSOs (Giguere, Kennedy, and Yackly, 1997).

This kind of information management is crucial to increasing the cost effectiveness of O&M programs. Combined with economic data, an optimal maintenance schedule is feasible. Using system-specific information, preventive maintenance is administered logically, taking into account local needs and conditions.

7.2.7.1 Research Needs

To achieve a level of maintenance that is cost effective, the effectiveness of O&M must be known in relation to the life-cycle costs. Therefore, research needs relate to a better understanding of overall sewer performance and costs, a need strongly tied into an integrated database such as that discussed in Section 7.2.5. Demonstration projects that carefully monitor costs and performance must be evaluated across different types of systems (e.g., sanitary systems, combined systems, large municipal systems, rural systems).

7.2.7.2 References

Giguere, P., Kennedy, B., and Yackly, C. (1997) Prioritizing collection system maintenance and rehabilitation projects using GIS and decision analysis software tools. *Collection Systems Rehabilitation and O&M: Solving Today's Problems and Meeting Tomorrow's Needs, Conference Proceedings*, Kansas City, Missouri. Alexandria, VA: Water Environment Federation.

Hardin, D., and Messer, C. (1997) Old data and new tools—maintaining the sewers that need it. *Collection Systems Rehabilitation and O&M: Solving Today's Problems and Meeting Tomorrow's Needs, Conference Proceedings*, Kansas City, Missouri. Alexandria, VA: Water Environment Federation.

7.2.8 Sewer and Tank Sediment Flushing

The fate and transport of solids in sewers remains largely unknown to researchers and designers alike. Current design methods call for minimum velocity or grade requirements, much like sewer design guidelines at the turn of the century (WEF/ASCE, 1982; Metcalf and Eddy, 1914). Recent research in Europe has focused on the fundamental but misunderstood phenomena that drive sediment behavior in sewers (Ashley, 1996). The results of 100 years of inadequate design practices have left many sewer owners with large maintenance problems and costs.

Self-cleansing sewers have been attempted with some success since antiquity (Pisano, Grande, and Novac, 1997). However, with great variation in the properties of solids, unwanted deposition occurs frequently in many sewers. Many methods for cleaning sewers are available. Pisano, Grande, and Novac (1997) give an overview of current technology. These methods include: power rodding—mechanical rods turn and cut through pipe deposits and roots—adequate for sewers up to 300 mm in diameter; balling, poly pigs, kites, and bags—an inflated rubber ball, kite, bag etc. is introduced to the sewer line and increases flow velocities, scouring deposited solids and grease—adequate for sewers up to 600 mm in diameter; jetting—uses a high-pressure hose, dragged mechanically through the sewer line to dislodge solids—usually a truck-mounted machine; and power bucket machine—a mechanical cleaning device usually used for areas that cannot be scoured by hydraulic methods (Pisano, Grande, and Novac, 1997).

Pisano, Grande, and Novac (1997) also discuss recent successes in permanent flushing mechanisms installed in sewers. Generally these are tanks or dams built into the sewer that release an unsteady dynamic wave at prescribed intervals to flush deposited solids. Variations on this technology have been used since the 1800s, but better fundamental understanding of sewer solids and maintenance needs allow better design of flushing schemes tuned to specific sewer conditions.

7.2.8.1 Research Needs

Two research needs are associated with sewer flushing. The first is fundamental research that will integrate fate and transport of solids with continuous simulation of sewer performance. This research should include development of adequate data monitoring for long-term evaluation of maintenance effectiveness and costs. The second research task involves the development of design criteria for automatic sewer flushing mechanisms. These are permanent structural designed elements of the sewer system such as those discussed by Pisano, Grande, and Novac (1997).

7.2.8.2 References

Ashley, R. ed. (1996) Solids in sewers. *Water Sci. Technol.* (G.B.) **33**: 9.

Metcalf, L., and Eddy, H.P. (1914) *American Sewerage Practice:* Volume 1, *Design of Sewers.* New York: McGraw-Hill.

Pisano, W., Grande, N., and Novac, G. (1997) Automated sewer flushing large diameter sewers. *Collection Systems Rehabilitation and O&M: Solving Today's Problems and Meeting Tomorrow's Needs, Conference Proceedings*, Kansas City, Missouri. Alexandria, VA: Water Environment Federation.

Water Environment Federation/American Society of Civil Engineers (1982) *Gravity Sanitary Sewer Design and Construction.* ASCE No. 60, New York: American Society of Civil Engineers. WPCF (WEF) No. FD-5. Alexandria, VA: Water Environment Federation.

7.2.9 Innovative Design of Sanitary and Storm Sewers

Aside from greater use of computers in sewer design, there have been few significant changes in modern sanitary sewer design in the last 30 years. Advances have primarily been in computer modeling of flows and system performance, but these are usually based on linear pre-computer methods such as the rational method and unit hydrograph methods for storm sewers and unit area design rates for I/I. The result of these design practices has had mixed results, with many over-designed sewers and some with less than acceptable reliability (Heaney et al., 1997). The lessons learned from the existing infrastructure should be used to develop a vision of future sewers that includes life-cycle costing, data management and control, I/I control, innovative technologies, source controls, etc. (Heaney et al., 1997). For this vision to be formulated, a logical estimate of future trends in land use and transportation must be made. Using the past as a guide, it is informative to look at the land use patterns of the last 50 years as a period in which the automobile dominated transportation, and this in turn helped drive land use patterns to zoned, separate uses and suburban sprawl (Heaney et al., 1997). Likewise, it is envisioned that the automobile will not disappear from the landscape in the near future. However, in another 50 years, land use and transportation are likely to be quite different than they are today.

Sanitary and storm sewer owners of the future cannot afford to repeat past mistakes. The long-term performance of the system must be maintained is services are to be cost effective. The effects of life-cycle costs driving the decision must be reckoned with; contracts that include a vested interest in the performance of the system over a long period will likely replace short-term construction contracts (Heaney et al., 1997). The control of the system will be synchronized with treatment plant operation and receiving water monitoring. This mandates that permanent monitoring stations be designed as an integral part of the collection system. The future sewer systems should be adaptable to new technology as it becomes available.

7.2.9.1 Research Needs

This research area is one of evolution in engineering design. In order to properly assess what the future may hold, lessons learned from current sewer infrastructure failures and successes must be assimilated into future design practice. The focus of future collection system design will be one of integration and control. The system will be viewed as an integral part of the urban water budget, urban land use, and the environment. To this end, the data analysis and control technology currently available should be used to create integrated models of the urban–environment interface.

7.2.9.2 Reference

Heaney, J.P., Wright, L.T., Sample, D., Urbonas, B., Mack, B., Schmidt, M., Solberg, M., Jones, J., Clary, J., and Brown, T. (1997) *Development of Methodologies for the Design of Integrated Wet-Weather Flow Collection/Control/Treatment Systems for Newly Urbanizing Areas,* draft report to US EPA. Cincinnati, OH: National Risk Management Research Laboratory.

7.3 Storage and Treatment

The economics of treating wastewater and stormwater during wet weather usually dictate that treatment be accompanied by some form of storage. Treatment costs for infrequent events generally outweigh storage costs, giving incentives to store some portion of the storm volume. The treatment used may take many forms, from combined sewage stored and released into the collection system for secondary or tertiary treatment at the wastewater treatment plant (WWTP), to simple sedimentation of stormwater in the storage facility itself. Storage also may be of several types, from use of existing pipe capacity to store wet weather flows in-line to off-line tanks or ponds. Another storage concept is the design and construction of new, oversized pipes to provide more system storage. This area has received little attention. The concept has several advantages over above-ground storage, in that the extra storage could be provided below-ground and constructed during rehabilitation and renovation projects. Auxiliary high-rate treatment may also be a cost-effective way to treat by-passed volume that would otherwise not be treated. This section introduces the rich history of research found in the engineering literature on storage and treatment.

High-rate treatment facilities have shown promise in treating wet weather flows in recent years. Sections 7.3.3 through 7.3.6 discuss areas of high-rate treatment that have been successfully demonstrated but require more fundamental knowledge of performance and costs before broad application of these technologies can be realized. High-rate treatment may be important for reducing wet weather impacts on receiving waters by providing greater treatment rate than traditional treatment methods, however this comes at the expense of (usually) providing a lower level of treatment. High-rate treatment may be divided into two areas: altered operating procedures of WWTPs to accept larger flows at reduced levels of treatment, and facilities specifically designed to accept high flow rates while providing a minimum level of treatment.

High-rate treatment may also be broken into two areas by the type of pollutant treated: solids or bacteria. Bacteria control through disinfection is a common goal of CSO control strategies (US EPA, 1993). Several technologies are available today, including chlorination, ozonation, and ultraviolet irradiation techniques (Moffa, 1996) (see Section 7.3.5. High-rate sedimentation is discussed in section 7.3.6. This technology involves use of chemicals to increase sedimentation rates. High-rate solids removal may also be accomplished through use of vortex separators, discussed in Section 7.3.4. These devices have successfully treated CSOs in the United States, Canada, and Europe (Field, 1990; Field and O'Connor, 1996; Pisano, Thibault, and Forbes, 1990; Pisano, 1994).

An area of research that shows significant promise, though it has had limited application in the United States, is the use of WWTPs to treat WWFs. High-rate operation of WWTPs involves changing the function of certain components of the WWTP to accept higher flow rates. This may be accomplished through step feeding (WEF, 1997), through the use of aeration tanks as primary settling devices (Nielsen, Carstensen, and Harremoes, 1996) or by other means of increasing treatment component capacity. This is a critical research area and highlights the importance of integrating the operation of collection systems with their associated WWTP.

Innovative work in storage-treatment system design and operation has been an active area of research. Van Buren, Watt, and Marsalek (1996) evaluated internal pond baffles in Kingston, Ontario, and found that extended hydraulic residence times and prevention of flow short-circuiting result in increased particulate settling and associated contaminant removal. Green and Martin (1996) evaluated the benefits of constructed reed beds in treating stormwater overflows in terms of reductions in discharges of BOD_5, TSS, ammonia, and total organic nitrogen. The design, evaluation, and application enhancements for swirl and vortex technologies for flow regulation and reduction of settleable solids were discussed by Field and O'Connor (1996). Booker, Ocal, and Priestly (1996) discuss the use of magnetite-assisted sedimentation and high-rate filtration for treatment of storm-induced sewer overflows. Werner and Kadlec (1996) evaluated the performance of constructed wetlands receiving wet weather runoff. Storage–treatment systems for storm-induced flows exhibit a wide range of configurations and treatment processes. These systems should be viewed in the context of integrated wet weather management, playing an important role in a system that includes source control, infiltration and reuse, conveyance, storage, treatment, and ultimate disposal. The literature reviewed in this section reveals a wide-ranging and rich history of active research and applications. The reader should refer to the citations in this section for a deeper appreciation of this field.

Listed in Table 2–8 are 31 research needs related to storage/treatment of WWFs. Many of the topics are specific to particular technologies or demonstration projects, but share important concepts. The 31 topics were grouped into 10 sub-topics, though not all sub-topics are specifically mentioned. This is because many areas are redundant from a research perspective, or little literature was found on the topic. That does not necessarily reflect the relative importance of the topics.

Section 7.3.2 covers research topics related to the problem of sanitary sewer overflows. Two areas from Table 2–8 are covered in this section: CSO concepts for SO control and SO corrective action. The next four sections, 7.3.3 through 7.3.6, cover different aspects of high-rate treatment. Section 7.3.3, high-rate operation of WWTPs, covers five subtopics identified by other research needs assessments. Laboratory studies of high-rate operation, process control systems, retrofitting for WWFs, demonstration of biofilters, and impacts of WWFs on WWTPs are all related to areas covered in Section 7.3.3. Vortex separation facilities for the treatment of CSO (though the technology may be used in other areas of WWF treatment) are covered in Section 7.3.4. Two topics from Table 2–8 are covered here: CSO vortex controls and vortex/disinfection demonstration. High-rate disinfection technology is discussed in Section 7.3.5, covering five topics from Table 2–8. The effectiveness under highly variable flow conditions, pathogen detection, vortex/disinfection demonstration, high-rate disinfection and high rate ozonation demonstration are covered. Innovative solids separation technology is discussed in Section 7.3.6, covering two topics from Table 2–8: high-rate sedimentation and magnetic separation. General aspects of solids handling are discussed in Section 7.3.7, covering three topics from Table 2–8. Design of release systems, the control of suspended solids and the control of dissolved solids are covered. Two topics are discussed in Section

7.3.8: treatment of toxins and treatment of heavy metals. Use of enhanced natural systems is covered in Section 7.3.9, specifically the use of enhanced infiltration and wetlands for treatment and disposal of urban runoff. This section covers five topics from Table 2-8: groundwater injection, application rates for land disposal, wetlands systems, constructed vegetation cells, and long-term effectiveness of infiltration systems. Best management practices are discussed in Section 7.3.10, which covers four topics from the table. Litter control systems, runoff control using compost systems, BMP effectiveness, and vegetative management practices are all discussed in the BMP section. The costs of operation and maintenance of storage treatment systems are covered in Section 7.3.11. The grouping of needs related to storage and treatment research is shown in Table 7–4.

One sub-topic listed in Table 2–8 was not covered in the 10 subsections of Section 7.3: the storage facilities design manual. Design manuals serve an important function in the transfer of information between researchers and practitioners. They also serve as a benchmark of engineering knowledge. Two important benchmarks have recently been published: *The Design and Construction of Urban Stormwater Management Systems* by the ASCE and WEF (1992); and *Stormwater Best Management Practices and Detention for Water Quality, Drainage and CSO Management* by Urbonas and Stahre (1993). These two volumes cover most of the state of knowledge regarding storage systems. The source of this topic in Table 2–8 is the US EPA report *Risk Management Research Plan for Wet Weather Flows* (Field et al., 1997). The discussion of this topic reveals that the scope of the project includes compiling existing data on the effectiveness of storage, verifying recommended approaches through modeling, and publishing a design manual. This topic was not included as a separate research topic because it would only be appropriate after significant progress had been made on the other aspects of storage and treatment of wet weather flows covered in this section. Upon completion of related storage topics, innovations in design should be included in a new "milestone" engineering guideline.

Another topic listed in Table 2–8 that is not covered in the following subsections is demand management for automobiles. This topic is covered in various forms throughout this report. See Sections 3.0, 3.2, and 3.3 for information regarding automobiles and wet weather pollution. Other items from Table 2–8 not covered in this section are the Environmental Technology Verification pilot project (ID# 145 from Table 2–8), and the performance of WWF controls in cold climates. The ETV pilot project is a project through the US EPA to provide performance and cost data on control technology. Evaluation is performed by a disinterested third party on proprietary control technology. This is an important project for wet weather control users, but it does not involve research. Cold climate research is a fairly active area, and the literature on the hydrologic effects of cold climates is considerable. However, little research has been done on the performance of WWF controls in cold climates, especially in urban areas. This area is important, and fundamental research that links known cold-climate hydrology and receiving water biology with performance information on controls should be done. The role of urban snowmelt is mentioned in Section 3.4.

Two broad topics in Table 2–8 that are not mentioned in the detailed sub-sections that follow are the integration of flood and pollution control works and the integration of landscape architecture in wet weather management systems. The integration of flood and pollution control works is a critical area of research and has been covered in Chapter 2.0. The integration of landscape architecture and wet weather management is covered in Chapter 8.0.

7.3.1 References

American Society of Civil Engineers (ASCE)/ Water Environment Federation (WEF) (1992) *Design and Construction of Urban Stormwater Management Systems*. New York: American Society of Civil Engineers; Alexandria, VA: Water Environment Federation.

Booker, N.A., Ocal, G., and Priestly, A.J. (1996) Novel high-rate processes for sewer overflow treatment. *Water Sci. Technol.* **34** (3–4): 103–109.

Field, R. (1990) Combined sewer overflows: Control and treatment. Moffa, P.E., ed., *The Control and Treatment of Combined Sewer Overflows*. New York: Van Nostrand Reinhold.

Field, R., and O'Connor, T.P. (1996) Swirl technology: Enhancement of design, evaluation, and application. *J. Environ. Eng.* **122** (8): 741.

Field, R., Borst, M., Stinson, M., Fan., C-Y., Perdek, J., Sullivan, D., and O'Connor, T. (1997) *Risk Management Research Plan for Wet Weather Flows,* EPA/600/R-96/140. Cincinnati, OH.

Green, M.B., and Martin, J.R. (1996) Constructed reed beds clean up storm overflows on small wastewater treatment works. *Water Env. Res.* **68** (6): 1054–1060.

Moffa, P.E., ed. (1996) *The Control and Treatment of Industrial and Municipal Stormwater*. New York: Van Nostrand Reinhold.

Table 7–4. Research Needs to Improve the Storage and Treatment (Unprioritized)

Section	*Table 2–8 ID #*	*Research Topic*
7.3 Storage Treatment		
7.3.2 Sanitary Sewer Overflows	133	CSO concepts for SSOs
	134	SO corrective action
	139	Triple purpose storage
7.3.3 High Rate Operation of WWTP	115	Laboratory studies of high-rate treatment systems
	116	Control systems to optimize options
	132	Retrofitting DWF control facilities to increase stormwater control
	137	Demonstration of biofilters for high-rate treatment
	146	Biofilm processes and biofiltration
	148	Impact of WWFs on WWTPs
7.3.4 High Rate Treatment—Vortex Separators	126	CSO vortex controls
Separators (also in 7.3.5)	135	Vortex/disinfection treatment demonstration
7.3.5 High Rate Treatment – Disinfection	117	Effectiveness of disinfection with variable flows
	123	Disinfection/pathogen detection
	136	High-rate disinfection
	138	High-rate ozonation pilot project in NY
(also in 7.3.4)	135	Vortex/disinfection treatment demonstration
7.3.6 High Rate CSO Treatment– Magnetic and Chemical Additives	130	High-rate sedimentation
	131	Magnetic separation
7.3.7 Control of Solids	111	Design of storage/release systems to maximize pollutant control
	120	Control of suspended solids
	122	Dissolved solids removal
	127	Cross flow plate settlers
7.3.8 Toxics and Metals	113	Treatment of heavy metals in urban runoff
	149	Endpoints of toxicants in detention ponds

Table 7–4, cont. Research Needs to Improve the Storage and Treatment (Unprioritized)

7.3.9 Wetlands and Land Disposal	112	Evaluation of groundwater injection systems
	118	Application rates for land disposal of urban runoff
	119	Wetland systems
	141	Constructed vegetated treatment cells
	145	Long-term effectiveness of infiltration systems
	140	Storage/wetlands treatment demonstration in Onondaga County, NY
7.3.10 BMP Effectiveness	143	BMP design/effectiveness
	128	Runoff control using compost
	124	Continuous deflective system for litter control
	144	Vegetative management practices
	103	Aquatic & non aquatic vegetative management
7.3.11 O&M Costs	114	Improved knowledge of O&M costs

Nielsen, M.K., Carstensen, J., and Harremoes, P. (1996) Combined control of sewer and treatment plant during rainstorm. *Water Sci. Technol.* **34** (3–4): 181–187.

Pisano, W.C. (1994) Operational experience with vortex solids separators for combined sewer overflow. Marsalek, J. and Torno, H., eds., *Proceedings of the 6th International Conference on Urban Storm Drainage*, Niagara Falls, Canada.

Pisano, W.C., Thibault, N., and Forbes, G. (1990) Vortex solids separator. *Water Env. Technol.* **2** (5): 64–71.

Urbonas, B., and Stahre, P. (1993) *Stormwater Best Management Practices and Detention for Water Quality, Drainage, and CSO Management*. Englewood Cliffs, NJ: PTR Prentice-Hall.

US EPA (1993) *Combined Sewer Overflow Control Manual*, EPA/625/R-93/007. Cincinnati, OH.

Van Buren, M.A., Watt, W.E., and Marsalek, J. (1996) Enhancing the removal of pollutants by an on-stream pond. *Water Sci. Technol.* **33** (4–5): 325–332.

Water Environment Federation (1998) *Urban Runoff Quality Management*. WEF Manual of Practice No. 23, Alexandria, VA: Water Environment Federation; ASCE Manual and Report on Engineering Practice No. 87, Reston, VA: American Society of Civil Engineers.

Water Environment Federation (1997) *Automated Process Control Strategies*. Alexandria, VA: Water Environment Federation.

Werner, T.M., and Kadlec, R.H. (1996) Application of residence time distributions to stormwater treatment systems. *Ecol. Eng.* 7 (3): 213–221.

7.3.2 Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are an important problem in the United States, especially in light of recent regulatory attention from the US EPA. The primary causes of SSOs are inflow and infiltration (I/I), pipe clogging, and pipe breaks. Jurgens and Kelso (1996) cite excessive wet weather flows as causing 20% of SSOs in Fayetteville, Arkansas, and Clemente and Cardozo (1996), 40%, in Miami, Florida. The proceedings of the 1996 national conference on SSOs shows that 27% of SSOs result from I/I, 43% from pipe blockages, 12% from pipe breaks, 11% from power failure, and 7% from insufficient system capacity (US EPA, 1996). These results were from a sample of six communities in the United States. Field and O'Connor (1997) address the implications of I/I rehabilitation as an SO abatement strategy. Sewer rehabilitation to remove I/I is very costly, as discussed in Section 7.2.7. Some systems report as much as 80% of I/I result from privately owned sources, so rehabilitation may not remove enough extraneous flow to alleviate the SO problem (Field and O'Connor 1997). Therefore, remedial actions using CSO treatment techniques may prove more cost effective. These actions include: maximizing the flow to the wastewater treatment plant (WWTP) using flow-equalization techniques, maximizing treatment capacity by retrofitting, installing parallel processes or designing new high-rate treatment plants, or installing satellite treatment facilities (Field and O'Connor 1997).

7.3.2.1 Research Needs

The research needs for control of SSOs are closely related to those for CSO control and other forms of high-rate treatment, including high-rate operation of WWTPs and flow maximization to the WWTP. In addition, it is important to look at rehabilitation costs and total benefits. While I/I control may not prove cost effective for controlling SSOs as argued by Field and O'Connor (1997), the combined benefits of improved sewer performance and reduced long-term pumping and treatment costs achieved from I/I control, in addition to SO reduction, may prove cost effective for some systems. Therefore this research area would greatly benefit from a careful accounting of the life-cycle costs of various rehabilitation/treatment alternatives.

Technical knowledge regarding SO abatement is also directly tied to maintenance effectiveness research as discussed in Section 7.2.7. I/I is not the only cause of SSOs that would benefit from other research topics. Other major causes of SSOs, e.g. pipe blockages, breaks and capacity limitations should be investigated to determine how much volume is lost from SSOs annually as a result of maintenance needs. Because it is not strictly a wet weather problem (dry weather SSOs may occur), research into this area should encompass all causes of SSOs, as dry weather discharges are generally more harmful to the environment. Elimination of a portion of SSOs may be an important result of an effective, preventive maintenance program, such as that discussed in Section 7.2.8. Once again, the economic benefit of life-cycle costing is an important factor in looking at all of the SO-abatement alternatives.

7.3.2.2 References

Clemente, A.J., and Cardozo, R.W. (1996) Dade County's mandated improvement program to reduce sanitary sewer overflows. *National Conference on Sanitary Sewer Overflows (SSOs).* EPA/625/R-96/007. Washington, DC: US EPA Office of Water,

Field, R., and O'Connor, T. (1997) Control strategy for storm generated sanitary sewer overflows. *J. Env. Eng.* **123** (1): 41–46.

Jurgens, D.E., and Kelso, H.M. (1996) Sewer rehabilitation: The techniques of success. *National Conference on Sanitary Sewer Overflows (SSOs)*, EPA/625/R-96/007. Washington, DC: US EPA, Office of Water.

US EPA (1996) *National Conference on Sanitary Sewer Overflows (SSOs)*, EPA/625/R-96/007. Washington, DC: Office of Water.

7.3.3 High Rate Operation of Wastewater Treatment Plants

Wastewater treatment plants (WWTPs) may be subject to high wet weather flows due to I/I or combined sanitary and storm flow from a portion of the collection system combined by design.

Abatement of overflows and system surcharges may be expensive, and could include system rehabilitation, construction of storage facilities, or end-of-pipe treatment works. Therefore, maximizing treatment plant capacity may be a very attractive option. This is accomplished by removing hydraulic restrictions in the collection system or the treatment works, or by using storage facilities to equalize flows (Field and O'Connor, 1997). However, additional storage needed to equalize flow may be reduced if the WWTP itself is operated in a fashion that allows high flow rates. High-rate operation of WWTPs may take several forms; including step-feed control (WEF, 1997), use of aeration tanks as settling basins (Nielsen, Carstensen, and Harremoes, 1996), and modification of treatment processes to allow for a higher rate of treatment (Booker, Ocal, and Priestly, 1996; Field and O'Connor 1997). WEF (1997) provides a case study of real-time control of WWTP operation in Hamilton, Ontario. During periods of wet weather flow, the WWTP switches operating policy to step feed the secondary clarifiers from the aeration basins. This avoids WWTP by-passes that would normally occur to prevent sludge blanket wash-out (WEF, 1997). Step feeding reduces the solids loading to the secondary clarifiers, allowing greater storm-generated volume to be treated without wash-out. This operating policy has reduced by-pass volume by an order of magnitude (WEF, 1997). Nielsen, Carstensen, and Harremoes (1996) detail a case study in Denmark that has shown improvements over the step-feed process control method. In this case study, careful data collection of system input and performance are used to control the WWTP at or near hydraulic and biologic capacity. Booker, Ocal, and Priestly (1996) provide information on increased settling efficiency achieved through use of chemical coagulation and magnetic-assisted sedimentation. Research is being conducted on magnetic sedimentation at a demonstration facility in Sydney, Australia (Booker, Ocal, and Priestly, 1996). While showing promise, this process is being refined to achieve lower operating costs and increased performance. Chemical coagulation is also being tested as a means of allowing for high-rate filtration (Booker, Ocal, and Priestly, 1996). Solids are chemically treated to enhance coagulation and flocculation, in turn enhancing settling and allowing for removal in filters that allow large hydraulic loading (Booker, Ocal, and Priestly, 1996).

7.3.3.1 Research Needs

High-rate operation of treatment works is a fertile area of research, with the potential for large economic benefits. Along with more demonstration of high-rate approaches, integration of high-rate treatment and control of the collection system is needed. This may lead to an eventual overall maximization of system resources, including collection system storage and maximized flow through the WWTP via high-rate operation and flow equalization. To achieve this objective, proper identification of high-rate performance is needed. This would allow life-cycle economic trade-offs between alternatives to be examined.

7.3.3.2 References

Booker, N.A., Ocal, G., and Priestley, A.J. (1996) Novel high-rate processes for sewer overflow treatment. *Water Sci. Technol.* (G.B.) **34** (3–4): 103–109.

Field, R., and O'Connor, T. (1997) Control strategy for storm generated sanitary sewer overflows. *J. Env. Eng.* **123** (1): 41–46.

Nielsen, M.K., Carstensen, J., and Harremoes, P. (1996) Combined control of sewer and treatment plant during rainstorm. *Water Sci. Technol.* **34** (3–4): 181–187.

Water Environment Federation (1997) *Automated Process Control Strategies*. Alexandria, VA: WEF.

7.3.4 High Rate CSO Treatment—Vortex Separators

Vortex separators are a common means of treatment for combined sewage. Bernard Smisson, in Bristol, England, first conceived of Vortex separators (Moffa, 1993). Smisson began his work in 1946 and formulated an idea of treating combined overflows at the point of discharge. Two of these original devices were constructed in Bristol in 1963 and are still in use today. The design concept was to have a small device that would separate solids from overflow, with the concentrated solids being passed back to the interceptor sewer and ultimately to the WWTP. Overflow, cleansed of much of the gross settle-able solids, was allowed to discharge into the receiving waters. Vortex separators (or swirls) achieve these design concepts by routing the flow through a circular path to achieve a type of vortex. Heavier particles are drawn toward the outer diameters and allowed to be drawn downward through ever smaller diameter paths and ultimately out a bottom drain or foul sewer, to be routed to the interceptor (Moffa, 1990). Flow containing smaller particles is allowed to discharge over the top of the device, thus achieving the desired separation. After conducting extensive hydraulic research on the forces involved with these units in the 1970s, the LaSalle Hydraulics Laboratory reported that the units function with a combination of gravitational and vortex separation in a controlled manner (Moffa, 1993). Vortex technology has advanced since Smisson's original concept. The US EPA conducted research and demonstration projects in the 1970s, developing a design now known as the US EPA Swirl. German designers have modified this design and market a device known as the Fluidsep (Moutal, Kloman, and Gaffoglio, 1994; Pisano and Brombach, 1994). Engineers in the United Kingdom have also modified the vortex separator and produced a model known as the Storm King (Moutal, Kloman, and Gaffoglio, 1994). In addition to solids separation, vortex separators remove floatables via a trap near the top of the unit (Moutal, Kloman, and Gaffoglio, 1994).Currently in the United States more than 50 vortex units are in operation (Moutal, Kloman, and Gaffoglio, 1994). Many of these units are still being tested for removal efficiencies and are often used in conjunction with storage facilities and disinfection processes (Field and O'Connor, 1996). A project in Flushing Bay in New York City is testing the three major vortex designs, primarily for floatables removal (Moutal, Kloman, and Gaffoglio, 1994).

7.3.4.1 Research Needs

Because a number of vortex separators are actively monitored or are about to be actively monitored, it would be appropriate to develop an unbiased review and database of all existing data for the various incarnations of vortex separators. Existing designs could then be modified in detail and the pros and cons of each type identified. A detailed design manual should be compiled from existing installation experience which covers all modern design alternatives, and long-term monitoring should be continued to determine appropriate life-cycle costs and performance.

7.3.4.2 References

Field, R., and O'Connor, T.P. (1996) Swirl technology: Enhancement of design, evaluation, and application. *J. Environ. Eng.* **122** (8): 741.

Moffa, P.E. (ed.) (1990) *Control and Treatment of Combined Sewer Overflows.* New York: Van Nostrand Reinhold.

Moffa, P.E. (1993) *Vortex Technology for Controlling Treatment of Combined Sewer Overflows.* Westford, MA: New England Interstate Environmental Training Center.

Moutal, H., Kloman, L., and Gaffoglio, R. (1994) Alternative vortex technology demonstration project. *A Global Perspective for Reducing CSOs: Balancing Technologies, Costs, and Water Quality., WEF Specialty Conference Series Proceedings,* Louisville, KY. Alexandria, VA: Water Environment Federation.

Pisano, W., and Brombach, H. (1994) Operational experience with vortex separators for combined sewer overflow (CSO) control. Marsalek, J., and Torno, J., eds. *Urban Storm Drainage*. New York: American Society of Civil Engineers.

7.3.5 High Rate CSO Treatment—Disinfection

Pathogens are one of the primary pollutants of concern from combined sewer overflows (CSOs). Disinfection is an important part of reducing risks associated with recreational and potable uses of receiving waters. However, traditional means of disinfection at WWTPs are designed to handle relatively constant flows and are not well suited to reliably handling highly variable CSO flows (Field, 1990). Because of the characteristics of CSOs—the intermittency, quantities of suspended solids, temperature variations, and variable bacterial quality—disinfection at WWTPs typically involves chlorine gas or sodium hypochlorite exposure (Field, O'Shea, and Brown, 1993). Other concerns involving disinfection of CSOs are that chlorine residuals may not be acceptable to the receiving water ecology, the disinfection unit may have to be unmanned and must be able to handle intermittent flows, and traditional indicator species such as fecal coliform may not be acceptable because runoff quantities may increase without corresponding increases in pathogens (Field, O'Shea, and Brown, 1993; O'Shea and Field, 1992).

Other disinfection technologies have shown promise in CSO disinfection. Boner et al. (1995) describe a bench scale test that used an ultraviolet disinfection unit installed in conjunction with a modified vortex separator (MVS/UV). The effectiveness of the disinfection unit depended on the solids removal efficiency in the vortex separator, and this study recommended that the MVS/UV be demonstrated at a full-scale installation. This recommendation was heeded, and a full-scale demonstration of a number of CSO abatement technologies is being conducted in Columbus, Georgia. (Boner and Turner, 1996). This demonstration project includes UV, chlorination/ dechlorination, and peracetic acid disinfection. Results of this project have not been reported.

7.3.5.1 Research Needs

A primary research need is to develop better means of measuring potential pathogenic waterborne bacteria. Traditional indicator organisms are unreliable for health-risk measurement, especially in areas that receive CSO and stormwater runoff (O'Shea and Field, 1992, 1993). One indicator will likely not be appropriate for every watershed; therefore studies should include a wide variety of storm-generated pollution and receiving waters (O'Shea and Field, 1992, 1993). Before control technologies can be compared and design guidelines developed for the disinfection of wet weather discharges, reliable means of measuring performance are crucial. Demonstration of disinfection technologies is also important; however, conclusive results should be dependent on reliable measures of pathogenic control.

7.3.5.2 References

Boner, M.C., and Turner, B.G. (1996) Demonstration testing of multiple wet-weather treatment technologies—Columbus, Georgia, program. *Conference Proceedings—Urban Wet-Weather Pollution, Controlling Sewer Overflows and Stormwater Runoff.* Alexandria, VA: Water Environment Federation.

Boner, M.C., Ghosh, D.R., Harper, S.R., and Turner, B.G. (1995) Modified vortex separator and UV disinfection for combined sewer overflow treatment. *Water Sci. Technol.* **31** (3–4): 263–274.

Field, R. (1990) Combined sewer overflows: Control and treatment. Moffa, P.E., ed. *The Control and Treatment of Combined Sewer Overflows*. New York: Van Nostrand Reinhold.

Field R., O'Shea, M., and Brown, M. (1993) The detection and disinfection of pathogens in storm-generated flows. *Water Sci. Technol.* **28** (3–5): 311–315.

O'Shea, M. L., and Field, R. (1992) Detection and disinfection of pathogens in storm-generated flows. *Canadian J. Microbiol.* **38** (4): 267–276.

O'Shea, M. L., and Field, R. (1993) The detection and disinfection of pathogens in storm-generated flows. Field, R., O'Shea, M., and Chin, K. (eds.), *Integrated Stormwater Management*, Boca Raton, FL: Lewis Publishers.

7.3.6 Advanced High Rate Treatment—Magnetic and Chemical Additives

The addition of chemicals to aid in sedimentation is standard practice in water and wastewater treatment, and is known to substantially increase sedimentation rates (Booker, Ocal, and Priestly, 1996). The intermittent, highly variable nature and the need for unmanned facilities makes treating wet weather flows with these processes more challenging (Field, 1990). Booker, Ocal, and Priestly (1996) give experimental results from Australia derived from chemical flocculation and magnetite-assisted sedimentation and high-rate filtration as a means to treat urban runoff. Another technology utilizing magnetic forces, high-gradient magnetic separation, has also been used to treat urban runoff with success (Field, 1990). A demonstration facility in Albany, New York used chemical additives to enhance treatment of CSO and raw sewage. Activated carbon was added to the flow to remove dissolved organics, then alum was added to aid in clarification (Field, 1990). Polyelectrolyte was added followed by a flocculation period. Gravity settling was then followed by filtration and disinfection. Reclaimed and reused chemicals were part of this demonstration (Field, 1990). Booker, Ocal, and Priestly (1996) report on use of polyelectrolytes to enhance flocculation and chemical coagulation. In pilot experiments, polyelectrolytes were added to SSOs, along with an inorganic coagulant (alum), and magnetite (iron oxide) to aid in sedimentation (Booker, Ocal, and Priestly, 1996). Initial results were promising for treatment of sewer overflows. Another phase of this study tested the addition of a coagulant (aluminum sulfate) and a high molecular weight cationic polyelectrolyte to raw sewage (Booker, Ocal, and Priestly, 1996). This mixture was then filtered using a more coarse filter than normally used for raw sewage. The flocculated and coagulated sewage was filtered at a high-rate at the pilot study scale (Booker, Ocal, and Priestly, 1996). These experiments showed promise in high-rate physicochemical separation. Delaporte (1996) reports on promising research in use of lamellar decantation in treating storm-induced flows. This process uses a flocculation and coagulation reactor in combination with lamellar modules, which are used in physicochemical treatment of water and wastewater. Results show COD and SS reductions of 60 to 85%. Averill et al. (1996) report on an integrated CSO treatment facility in Toronto. This pilot test used chemical coagulant additives, a vortex separator (Storm King Dynamic Separator), a clarifier, and UV disinfection. The average effluent TSS concentration was 65 mg/L when using the chemically assisted coagulant (Averill et al., 1996).

7.3.6.1 Research Needs

Research should focus on process refinement and interaction with other high-rate treatment processes, e.g., vortex separation and disinfection, as shown in Averill et al. (1996). The Toronto pilot test (Averill et al., 1996) is an excellent model in developing process demonstration facilities, as all processes may be removed or an additional process added in order to monitor operational performance on a wide variety of process train configurations.

7.3.6.2 References

Averill, D., Chessie, P., Mack-Mumford, D., Marsalek, J., and Weatherbe, D. (1996) Pilot testing of physical-chemical treatment options for CSO control. *Conference Proceedings—Urban Wet-weather Pollution, Controlling Sewer Overflows and Stormwater Runoff.* Alexandria, VA: Water Environment Federation.

Booker, N.A., Ocal, G., and Priestly, A.J. (1996) Novel high-rate processes for sewer overflow treatment. *Water Sci. Technol.* (G.B.) **34** (3–4): 103–109.

Delaporte, C. (1996) Treating rainfall-induced discharges from urban areas using lamellar decantation. *Conference Proceedings—Urban Wet-weather Pollution, Controlling Sewer Overflows and Stormwater Runoff.* Alexandria, VA: Water Environment Federation.

Field, R. (1990) Combined sewer overflows: Control and treatment. Moffa, P.E., ed., *Control and Treatment of Combined Sewer Overflows*. New York: Van Nostrand Reinhold.

7.3.7 Control of Solids

Removing suspended solids is perhaps the oldest method for controlling water pollution. If allowed to settle by gravity, suspended solids are removed relatively easily and do not require biological or chemical treatment. However, the treatment of suspended solids is still a complex engineering problem because of constraints related to the settling velocities of small particles in water. Removing solids is additionally important because other important pollutants are often either in solid form or adsorb onto solid particles. Nutrients, bacteria, synthetic organics, toxics, and heavy metals may all be part of the suspended solids load. Control of wet weather solids may be accomplished either by treatment or source control. Source control of suspended solids is covered in Section 7.1. Treatment of suspended solids may be broken into treatment utilizing strictly settling forces, or enhanced settling via chemical or magnetic additives (covered in Section 7.3.6). Gravitational settling treatment includes traditional detention and gravity settling, enhanced gravitational settling (i.e. plate settlers), or vortex separation (covered in Section 7.3.4).

Control and treatment of dissolved solids is a more complex engineering issue. Because they are not affected by gravitational forces, dissolved solids, along with colloidal particles, must be controlled by other means. Dissolved solids are more commonly treated by source control; e.g., BMPs related to erosion and site disturbance, or deicing salt management. However, Van Buren, Watt, and Marsalek (1996) report removing dissolved pollutants from a modified detention basin by using baffles to eliminate short circuiting. Wetland biota may remove selected dissolved pollutants. In an assessment of wetland treatment, Strecker (1993) reports that metals may form insoluble sulfides in wetland environments. Urbonas (1997) also cites biochemical reactions occurring in wetland and wet-pond environments that remove dissolved constituents. In general, dissolved solids treatment must rely on some form of reaction, while suspended solids may be treated chemically or physically.

7.3.7.1 Research Needs

The physics of particle behavior in water is fairly well understood; however, the added complications of flocculation, floatables, highly variable loads, and biologic activity make it difficult to accurately predict actual settling. Demonstration of innovations in outlet design, storage geometry, and the effects of loading variability should be encouraged. We must better understand physical aspects of settling basins, including mixing regimes, temperature effects, concentration effects, and velocity distributions. A better understanding of the physical processes may lead to more efficient designs and aid in other areas of treatment. Research on the treatment of dissolved solids should be part of a wetlands-treatment research program. This is a relatively active research area in the United States, and, in the monitoring of these systems, a better understanding of the biochemical reactions that take place in a wetland environment should be encouraged.

7.3.7.2 References

Strecker, E. (1993) The use of wetlands for stormwater pollution control. *National Conference on Urban Runoff Management: Enhancing Urban Watershed Management at the Local, County and State Levels*, EPA/625/R-95/003. Cincinnati, OH: US EPA.

Van Buren, M.A., Watt, W.E., and Marsalek, J. (1996) Enhancing the removal of pollutants by an on-stream pond. *Water Sci. Technol.* (G.B.) **33** (4–5): 325–332.

Urbonas, B. (1997) An assessment of stormwater BMP technology. Heaney, J.P. et al., eds., *Development of Methodologies for the Design of Integrated Wet-Weather Flow Collection/Control/Treatment Systems for Newly Urbanizing Areas*, draft report to US EPA. Cincinnati, OH: National Risk Management Research Laboratory, Office of Research and Development.

7.3.8 Characterization and Treatment of Toxics and Metals

Heavy metals (cadmium, copper, lead, and zinc) and many toxics (e.g., PCBs, dioxin) are environmentally persistent, and therefore accumulate in receiving water sediment, settled sludge from WWTPs or satellite treatment facilities, or in the surficial soils of permeable infiltrating areas (Boller, 1997). An estimated 50 to 80% of metals are washed off from roofs and streets (Boller, 1997). Forster (1996) found a prominent first flush of metals from urban roof runoff in Germany.

Physical treatment (e.g., gravitational settling, filtration, vortex separation) tends to transfer these pollutants from one segment of the urban waste stream to another. For example, settled metals accumulate in benthic environments such as the bottom of detention ponds (Ab Razak, Li, and Christensen, 1996). Routine maintenance may be performed by dredging the detention basin bottom. The result is contaminated soil waste that may have to be landfilled. Therefore, source control is a critical part of toxin and metal control (Forster, 1996; Boller, 1997). PAHs, PCBs, ^{137}Cs, and ^{210}Pb are among other persistent pollutants that associate with clay, silt, and organic carbon particles in runoff and may ultimately accumulate in sediment beds (Ab Razak, Li, and Christensen, 1996). Forster (1996) reported zinc and copper concentrations from roof runoff that pose an environmental hazard to aquatic fauna even after strong dilution. Bijlsma et al. (1996) conducted studies on canal sediments in the Netherlands and found high concentrations of metals. The top 15-cm layer had concentrations of zinc as high as 1400 mg Zn/kg, copper as high as 281 mg Cu/kg, and lead as high as 562 mg Pb/kg. The sediment over 15 cm deep had concentrations 20 to 50% higher, possibly indicating a diminishing load. Forster (1996) recommends that the first flush of roof runoff be conveyed to the WWTP via combined sewers. This management alternative assumes that the WWTP sludge will contain metals from other sources, and therefore the incremental metals added by diverting roof runoff will not add to the toxicity of the sludge. Boller (1997) indicates that innovative wet weather management systems such as enhanced infiltration are severely limited by the possible accumulation of heavy metals. Management alternatives such as combined sewers, separate systems, or infiltration schemes merely transfer metals to WWTP sludge, receiving water sediments, or local on-site soils, respectively (Boller, 1997).

7.3.8.1 Research Needs

Source control appears to be the only form of long-term control that will avoid build-up of persistent pollutants in the environment. Long-term, cross-disciplinary research—involving plumbers, automobile designers, architects, landscape architects, environmental and industrial engineers, and the public—is essential to effectively remove these pollutants from the urban environment (Boller, 1997). This research is critical and should be linked to on-site hydrology, infiltration and other re-use strategies, and wetland management. Aside from source control, it is important in the short-term to continue research into toxic impacts, bioaccumulation, and the fate and transport of waste through the urban hydrosphere, from the household level to its ultimate fate in the environment.

7.3.8.2 References

Ab Razak, I.A., Li, A., and Christensen, E.R. (1996) Association of PAHs, PCBs, ^{137}Cs, and ^{210}Pb with clay, silt and organic carbon in sediments. *Water Sci. Technol.* (G.B.) **34** (7–8): 29–35.

Bijlsma, M., Galione, A.L.S., Kelderman, P., Alaerts, G.L., and Clarisse, I.A. (1996) Assessment of heavy metal pollution in inner-city canal sediments. *Water Sci. Technol.* **33** (6): 231–237.

Boller, M. (1997) Tracking heavy metals reveals sustainability deficits of urban drainage systems. *Water Sci. Technol.* (G.B.) **35** (9): 77–87.

Forster, J. (1996) Patterns of roof runoff contamination and their potential implications on practice and regulation of treatment and local infiltration. *Water Sci. Technol.* (G.B.) **33** (6): 39–48.

7.3.9 Wetland Treatment and Land Disposal of Urban Runoff

While, technically, different forms of wet weather management, wetland treatment systems and land disposal techniques share some important concepts. Both are less infrastructure-intensive than sewer-based/receiving water discharge systems, and have similar benefits; namely both reduce flood peaks, may increase the local groundwater table, and may reduce pollutant discharges to receiving waters. Land application has the additional benefit of reducing outdoor landscape irrigation needs, while wetland systems may be incorporated into beneficial land uses such as parks and wildlife habitat (Knight, 1997). Important considerations of both practices have also been identified, namely possible soil contamination of persistent toxins and metals (see Section 7.3.8).

Wetlands used for treatment are complex systems requiring a close interaction between hydrologists, biologists, engineers, land-use planners, and urban managers. They require maintenance and careful design to maintain sustained benefits (Urbonas and Stahre, 1993). The literature in the constructed wetland field is broad. Habrel et al. (1997) give an overview of wetland systems for water pollution control. This volume highlights the advanced level of research activity in this area. Shutes et al. (1997) report on wetland systems for runoff treatment; pre-treatment consists of oil separators, spillage interceptors, and wetland forebays. This example of integrating innovative treatment schemes is important for the long-term success of these methods. In the United States, concerns about groundwater contamination have engendered somewhat more resistance to the application of infiltration systems than to constructed wetlands. However, in Tokyo, applications have been extensive and the increased baseflow in urban streams has been beneficial (Fujita, 1997).

7.3.9.1 Research Needs

Wetland treatment and land disposal of urban runoff are active research areas and further knowledge should be encouraged. Specifically, long-term treatment capabilities of both infiltration systems and wetlands should be investigated. It is also important that these systems be part of an integrated land-use/runoff management scheme. The land value benefits of riparian parks and wetland systems may even outweigh improvements in water quality. These systems will be a vital part of urban land and water management of the 21st century and as such it is important that research be continued in this area. The hydrologic considerations in designing these systems are crucial. Application rates of infiltration and acceptable hydrologic loading of wetlands are important for sustaining these systems. Regional differences are more pronounced than for other forms of treatment, and therefore demand acceptable hydrologic loading. The research aspects of wetland and infiltration disposal should focus on engineering better overall systems that increase land values through parks, provide treatment of runoff, and are part of a plan that includes source control, infiltration systems, and detention/wetland systems.

7.3.9.2 References

Fujita, S. (1997) Restoration of polluted urban watercourses in Tokyo for community use. Rowney, A.C., Stahre, P., and Roesner, L.A., eds., *Sustaining Urban Water Resources in the 21st Century*. Malmö, Sweden: Engineering Foundation Conference.

Habrel, R., Perfler, R., Laber, J., and Cooper, P., eds. (1997) Wetland systems for water pollution control 1996. *Water Sci. Technol.* (G.B.) **35**: 5.

Knight, R.L. (1997) Wildlife habitat and public use benefits of treatment wetlands. *Water Sci. Technol.* (G.B.) **35** (5): 35–43.

Shutes, R.B.E., Revitt, D., Munger, A., and Scholes, L. (1997) The design of wetland systems for the treatment of urban runoff. *Water Sci. Technol.* **35** (5): 19–25.

Urbonas, B., and Stahre, P. (1993) *Stormwater Best Management Practices and Detention for Water Quality, Drainage, and CSO Management*. Englewood Cliffs, NJ: PTR Prentice-Hall.

7.3.10 BMP Effectiveness

Best management practice (BMP) is an ill-defined term in the urban wet weather literature. BMP is used to describe everything from true management practices to any type of control facility, including large capital projects, that go beyond the common meaning of the term management alternative. Urbonas (1997) defines BMP as any practice to control and manage the quality and quantity of urban runoff, including structural and non-structural BMPs. Non-structural BMPs include: discontinuing or preventing use of a pollutant (e.g., pesticides, phosphorus detergents); programs to reduce site disturbance and erosion; public education on proper uses and disposal methods of chemicals, oils, pesticides, etc.; effective street sweeping, deicing, and leaf removal; elimination of illicit connections of wastewater lines to storm sewer lines; and O&M programs for public and private wet weather management facilities (Urbonas, 1997; Pitt et al., 1997; Schueler, 1995). Structural BMPs may include: minimizing directly connected impervious area, water quality inlet design—including catch basin design (e.g., deflective litter control design), infiltration practices, filter basins and filter strips, solids separation by gravity or vortex forces in wet and dry detention basins and vortex separators, and wetlands (Urbonas, 1997; Pitt, 1997; Yu and Nawang, 1993).

Currently there is no meaningful direct measure of the effectiveness of non-structural BMPs, largely because they rely more on behavior modification than on hardware-oriented means (Urbonas, 1997; Pitt et al., 1997). Non-structural BMPs tend to be common-sense practices; however there is little information on the costs of the necessary behavior modification and benefits derived thereof. Field performance data are available from a wide variety of structural BMP facilities (Urbonas, 1997). However, there is no standard method of measuring performance, and much data are reported in the theoretically flawed measure of "percent removal" (Urbonas, 1997).

7.3.10.1 Research Needs

Several critical research needs are associated with the application of BMPs. Most critical is developing a better understanding of how various BMPs fit into an integrated urban water management plan. To accomplish this, three research needs are evident: (1) a meaningful standard to quantify performance; (2) long-term performance and cost data (using the standard developed in #1) to prove that BMPs in fact are "best"; and (3) a process-level understanding of the various BMPs to improve current design practice. Current BMP design is an art, relying on the designer's intuition about what is appropriate for a given situation.

7.3.10.2 References

Schueler, T. (1995) *Environmental Land Planning Series: Site Planning for Urban Stream Protection.* Washington, DC: Center for Watershed Protection, and the Washington Council of Governments.

Pitt, R., Lilburn, M., Nix, S., Durrans, R., and Burian, S. (1997) *Guidance Manual for Integrated Wet-weather Flow (WWF) Collection and Treatment Systems for Newly Urbanizing Areas (New WWF Systems),* interim first year progress report to US EPA. Edison, NJ.

Urbonas, B. (1997) An assessment of stormwater BMP technology. Heaney, J.P., L.T. Wright, D. Sample, B. Urbonas, B. Mack, M. Schmidt, M. Solberg, J. Jones, J. Clary, and Brown, T., eds., *Development of Methodologies for the Design of Integrated Wet-Weather Flow Collection/Control/Treatment Systems for Newly Urbanizing Areas,* draft report to US EPA. Cincinnati, OH: National Risk Management Research Laboratory.

Yu, S.L., and Nawang, W.M. (1993) Best management practices for urban stormwater runoff control. Field, R., O'Shea, M.L. and Chin, K.K., eds., *Integrated Stormwater Management,* Boca Raton, FL: Lewis Publishers.

7.3.11 Improved Knowledge of Operating and Maintenance Costs

As discussed in Sections 7.2.6 and 7.2.8 for collection systems, knowledge of actual costs of maintenance activities is crucial to developing a beneficial maintenance plan. This is also true for the operators of storage/treatment facilities to minimize life-cycle costs. For example, based on construction expenditures, detention ponds may be an attractive storage and treatment option in areas where land value is relatively low. However, the administration of maintenance of storage works is crucial to maintain performance over time (Urbonas and Stahre, 1993). Not only are the costs of cleaning and maintaining detention ponds important as settled solids fill the volume of the pond, but the administration of these activities must be planned during the design stage so facilities are not abandoned (Urbonas and Stahre, 1993). Further consideration must be given to the potential of disposing contaminated sediments, as discussed in Sections 7.3.8 and 7.3.9.

7.3.11.1 Research Needs

Knowledge of life-cycle costs must be better understood to accomplish integrated performance criteria for an entire drainage system. As with collection systems, storage and treatment works must include careful documentation of the trade-offs incurred between maintenance and performance. To accomplish this goal, standardized performance criteria should be developed to understand how well existing facilities perform, and standardized accounting procedures should be developed to allow for cross-comparison. Demonstration of these performance criteria in actual basins would then lead to a better design criteria for engineers, and a better understanding of the life-cycle costs for operators.

7.3.11.2 Reference

Urbonas, B., and Stahre, P. (1993) *Stormwater Best Management Practices and Detention for Water Quality, Drainage, and CSO Management*. Englewood Cliffs, NJ: PTR Prentice-Hall.

CHAPTER 8.0

SYNTHESIS OF RESEARCH NEEDS AND CONCLUSIONS

8.1 Summary

This chapter discusses the results of our assessment of research needs in urban wet weather flows (WWFs). Three interrelated categories are included: combined sewer overflows, sanitary sewer overflows, and urban stormwater discharges, and each research need is considered in the following steps: (1) reviewing of all relevant literature; (2) reviewing of previous research needs assessments, including US EPA's 1996 Wet Weather Flows research planning report (Field et al., 1997); (3) soliciting ideas from interested professionals at a one-day workshop at the 1996 WEFTEC national meeting in Dallas; (4) holding extensive discussions with leading urban stormwater professionals; and (5) reviewing research needs with leading international experts at the September, 1997, Engineering Foundation Conference in Malmö, Sweden (Rowney, Stahre, and Roesner, 1998).

8.2 Methods for Doing Research Needs Assessments

Research needs can be assessed in a variety of ways. Five of the seven research needs assessments cited in this report were done by polling experts during a professional meeting. The remaining two needs assessments used an extensive literature review and the professional experience of a few experts as the basis for selecting topics. The research needs assessment can be viewed as a portfolio selection problem wherein the objective is to maximize the present value of the expected net benefits from research investments. Research is a risky investment. The objective is to select a project portfolio with a high probability of success just as investors choose among stocks, bonds, and other investment opportunities. While formal research planning models have been used for large research programs, most research funding organizations rely on less formal approaches. This assessment uses a wide variety of U.S. and international expertise to develop a sense of research needs. The project team believes that the final list is a fairly well balanced view of the problem.

8.3 Purposes of Urban Wet Weather Research Program

Many different entities support wet weather research. Among them is the Water Environment Research Foundation (WERF), which is supported by participating cities that generally prefer to support applied research involving well-defined tasks and a fairly high assurance of delivering results to the user community within three to five years. Therefore, WERF projects typically address discrete, targeted topics that involve relatively short study periods (one to two years). WERF project funding is awarded based on responses to a formal Request for Proposals (RFP). At present, this model dominates research funding in the United States and Europe, because the results reach the funding organizations in a short time frame. Two potential drawbacks of funding only relatively applied research projects is that such projects may tend to be less innovative, since the problem and often the solution are prescribed in the RFP, and such projects usually provide only limited support for training graduate students in the wet weather area. [Editor's note: WERF has now created a funding program for innovative research under its Emerging Technologies Program.]

At the opposite end of the spectrum is basic research, characterized by unsolicited proposals from universities and other research organizations wherein proposers present their ideas and request support for longer-term, basic research for which immediate utility may be unclear. It is more difficult for local utilities and agencies to justify supporting such activities. Even a federal action agency, such as US EPA, may have trouble justifying such longer-term investments. The National Science Foundation (NSF) provides this kind of support. Until recently, their funding related to urban stormwater has been scant. A current NSF/US EPA/USDA cooperative initiative on watersheds offers hope of better support in this area.

A potentially new dimension of future WWF research lies in the area of international cooperation. These essential, long-term experimental research are expensive and it is difficult to obtain continuing support in lean budget times. The emergence of the European Union as a major source of research support offers real possibilities for establishing internationally funded cooperative projects in key WWF areas.

8.4 Vision for the Benefits of Urban WWF Research

Concerted efforts since the late 1960s to clean up urban wastewaters and wet weather flows have achieved impressive results. Before then, the accepted fate of urban receiving waters was to serve as recipients of the unwanted by-products of urbanization including dry-weather- and wet-weather-transported wastes from urban, industrial, agricultural, forestry, mining, and other activities. Also, these same receiving waters were ditched, drained, sewered, and subjected to a wide variety of manipulations to serve human needs. In addition to water quality changes, these waters were severely impacted by hydrologic changes due to hydropower development, navigation, water supply, flood control, recreation, etc. The end product of these abuses was that citizens were conditioned to think of their waterways as undesirable kidneys of the city that were to be hidden and avoided.

Consequent to billions of dollars of expenditures on water quantity and quality improvements, we can now see the long-term benefits of these investments come to fruition in terms of revitalized urban waterfront areas. With WWFs managed and a desirable hydrology provided for receiving waters, citizens can enjoy the benefits of this important investment for themselves and for posterity.

8.5 Summary of Research Recommendations

A synthesis of seven compilations of research needs and a selection from this listing were presented in the previous five chapters. The compilation resulted in the 154 research projects listed in Table 8-1. From this list, a subset of 69 higher priority research projects were selected and one page summaries were prepared for each of these topics. The selected 69 projects are shown in Table 8-2. During the final screening, several criteria were used in the selection process:

- Inherent importance of the topic;
- Topic is an emerging area of concern for which few research results are available; and
- Topic is an important component of an integrative approach to WWFs.

The final 26 selected research topics (Table 8–3), are divided into two priorities. Priority 1 topics should be initiated first. They may be short- or long-term efforts. Priority 2 topics are also important but not as critical as the Priority 1 topics. In many cases, these final 26 topics are aggregations of the larger subset of high-priority research projects. The final results of the research needs assessment were organized into 10 categories: (1) sources and monitoring, (2) receiving water impacts, (3) other impacts, (4) management, (5) models and decision support systems, (6) watershed management linkages, (7) regulatory policies and financial aspects, (8) source controls, (9) collection system controls, and (10) storage/treatment systems. Summary discussions regarding these topics are presented in the subsections that follow.

Table 8–1. Composite List of Research Needs in Urban Stormwater Quality

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
	Sources and Monitoring								
1	Atmospheric deposition				4		6		2
2	Industrial sites						15		1
3	Thermal pollution						13		1
4	Use of dense rain gages and radar to describe storm patterns	11	3						2
5	Watershed response during winter conditions			9					1
6	Rainfall-runoff relationships for micro- storm management						9		1
7	Automotive sources						1	2	2
8	Construction sources						2		1
9	Litter sources						3		1
10	Build-up/wash-off processes in urban areas	1					5		2
11	Influence of land use on water quality		7			1.12			2
12	Fecal sources-use better indicators				9	1.2	11		3
13	Toxics sources and monitoring				17	3.1		12	3
14	Pesticide sources				25				1
15	Determine decomposition rate for various PAHs			3					1
16	Turbidity studies, settleability, particle sizes, etc.				18				1
17	Isotope tracking techniques for characterizing the nature of WWFs						14		1
18	Cross media issues				15				1
19	Flow meters to measure widely variable flows		5						1
20	Flow-weighted sampling devices for variable flows		6		19	1.3	12		4
21	Standards for sampling, analysis, and reporting for urban runoff pollutants	5							1
22	Cradle to grave tracking of urban water pathways and controls							17	1
23	Quality of roof runoff							10	1
	Receiving Water Impacts								
24	Behavior of urban runoff in mixing zones of rivers, lake, & estuaries	3	33			1.4			3
25	Feasibility of identifying "natural conditions" at the watershed scale			11					1
26	Impact of snowmelt on receiving water quality			6					1
27	Bioassay proc. for long-term exposures to heavy metal accum. in benthos	2	30	4					3
28	Fate of nitrogen inputs					1.11			1
29	Criteria for wet-weather quality standards	8	32						2
30	Mass balance of urban runoff and receiving water fluxes		31	5					2
31	Bioassay procedures for short-term intermittent exposures		29						1
32	Water quality response in water column & sediment	12							1
33	WWF physical stressors					1.5			1
34	Effect of urbanization on stream geomorphology						35		1
35	Indices to determine specific impacts of constituents e.g., BOD, metals				6		37		2
36	Small stream impacts					1.7			1
37	Sediment impacts & control					2.16			1
38	Large river impacts					1.8			1
39	Source water protection					2.4			1
40	Understanding regional differences in receiving waters			8	20				2
41	Stormwater-groundwater interactions	10				2.6			2
42	Vadose zone impacts					2.8			1

Table 8–1, cont. Composite List of Research Needs in Urban Stormwater Quality

No.	Title	Source							
		Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
43	Human health risk/ecosystem impact trade-offs						36		1
44	Groundwater pollution from highways							9	1
45	Evaluation of health risks					1.9		7	2
	Management								
46	Add solids handling to simulation models		35	14					2
47	Develop user friendly integrated decision support systems		42	15					2
48	Linkage of surface and subsurface phenomena		2						1
49	Interface simulation and optimization models		36			2.3			2
50	Analyze existing NURP, USGS, NPDES, and other data		38	16					2
51	Probabilistic performance criteria for wet weather control								
52	Integrate GIS to refine spatial analysis capabilities		4						1
53	Develop risk management methodologies	13				3.5		11	3
54	Combine available databases into a single database		39						1
55	Develop an integrated DSS for overall watershed evaluations						30		1
56	Watershed Ecosystem Model					2.14		16	2
57	Create and maintain an urban stormwater information repository					2.15			1
58	Develop more robust parameter estimation methods		34	13					2
59	Develop a watershed assessment methodology							19	1
60	Case studies of integrated stormwater management	16							1
61	Add real-time control to all aspects of urban stormwater models					4.17	25	3	3
62	Establish a network of urban research catchments			12				25	2
63	Watershed-based water quality standards			10					1
64	Methods for estimating the prob. distributions of dry and wet-weather flows		43	17					2
65	Riparian forest management					4.9			1
66	Criteria for model calibration/verification	14							1
67	Calibration of transport models using improved databases		14						1
68	Decision support systems with real-time control and all aspects of urban water							5	1
	Regulatory Policies and Financial Aspects								
69	Preparing effective and implementable NPS regulations				11				1
70	Areas where EPA can provide regulatory flexibility to achieve watershed goals.						27		1
71	Methods to allocate the costs of multi-purpose water projects		40						1
72	Cost/performance function data for stormwater controls	7			24		28		3
73	Quantify benefits of stormwater quality control		28					8	2
74	Contingent valuation to estimate the benefits of stormwater projects		41						1
75	How to develop sustainable watershed management programs								
76	CSO measures of success					4.10			1
77	Feedback on public involvement, participation techniques						31		1
78	How to translate public desires into action?				21		32		2
79	Stormwater management in new urban areas								
80	Feasibility of decentralized urban water management and privatization							26	1
81	Common elements of successes and failures.						33		1
82	Retrospective assessments of existing environmentally friendly developments				14				1
83	Environmental justice in management programs				23				1
84	Recognition of regional differences in appropriate management strategies				1				1

Table 8–1, cont. Composite List of Research Needs in Urban Stormwater Quality

No.	Title	Source							Count
		Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	
85	Mechanism for coordinating storm water research across agencies			7					1
86	Improve EPA use attainability methodologies								
87	Environmental ethics to reduce litter							13	1
	Controls								
88	Effectiveness of swales		9						1
89	Reuse of urban runoff as cooling water		21						1
90	Modifying urban surfaces to reduce hydraulic and pollutant loads						10		1
91	Urban drainage design improvements for micro-storms						7		1
92	Demand management for automobiles							22	1
93	Toxics sources reductions								
94	Improved methods of source reduction								
95	Stormwater reuse					2.5			1
96	Swales instead of curbs					2.6			1
97	Storm inlet device					4.12			1
98	Industrial runoff control					4.3			1
99	Roadway/airport deicing					4.5			1
100	Instrumentation & monitoring to evaluate sewer hydraulics		10						1
101	Laboratory & field studies of deposition & scour in sewers	4	12						2
102	Use of simulation models in storm sewer design		13						1
103	Aquatic & non aquatic vegetative management				22				1
104	Cost-effective ways to rehabilitate & replace old sewers		11			5.3			2
105	Sanitary sewer system design practices					5.4			1
106	Sewer maintenance effectiveness					5.2	20		2
107	Sewer and tank sediment. flushing					4.36	23		2
108	Innovative design of sanitary and storm sewers							23	1
109	Short and long-term performance of porous and permeable pavments							21	1
110	Sludge/solids disposal aspects of control options		24						1
111	Design of storage/release systems to maximize pollutant control		17				24		2
112	Evaluation of groundwater injection systems		18						1
113	Treatment of heavy metals in urban runoff		23						1
114	Improved knowledge of O&M costs	9		2	5				3
115	Laboratory studies of high-rate treatment systems		15						1
116	Process control systems to optimize performance of control options	15	25						2
117	Effectiveness of disinfection with highly variable flows		16						1
118	Application rates for land disposal of urban runoff		20						1
119	Engineering considerations in using wetland systems								
120	Control of suspended solids						18		1
121	Integrated systems for flood and pollution control including reuse						19		1
122	Dissolved solids removal						21		1
123	Disinfection/pathogen detection					1.1			1
124	Continuous deflective system for litter control					4.14	17		2
125	Storage facilities design manual					4.16			1
126	CSO vortex controls					4.18			1
127	Cross flow plate settlers					4.27			1

Table 8–1, cont. Composite List of Research Needs in Urban Stormwater Quality

No.	Title	Source: Torno 1986	Heaney 1986	CH2M Hill 1990	WERF/Bay Area 1996	EPA 1996	WERF 1996	Malmo 1997	Count
128	Runoff control using compost								
129	Cross connection identification					4.8			1
130	High-rate sedimentation					4.15			1
131	Magnetic separation					4.19			1
132	Retrofitting DWF control facilities to increase stormwater control					4.20			1
133	CSO concepts for SSO's					4.22			1
134	SSO corrective action					4.23			1
135	Vortex/disinfection treatment demonstration project					4.24			1
136	High-rate disinfection					4.26			1
137	Demonstration of biofilters for high-rate treatment at DWF plants					4.28			1
138	High-rate ozonation pilot project in New York, NY					4.29			1
139	Triple purpose storage for I/I, CSO, and DWF					4.30			1
140	Storage/wetlands treatment demo. in Onondaga County, NY					4.31			1
141	Constructed vegetated treatment cells					4.33			1
142	ETV pilot for WWF controls					4.34			1
143	BMP design/effectiveness					4.35			1
144	Vegetative management practices	6			10	4.6	16	20	5
145	Long-term effectiveness of infiltration systems				13				1
146	Biofilm processes and biofiltration							6	1
147	Performance of WWF controls in cold climates							18	1
148	Impact of WWFs on wastewater treatment facilities							24	1
149	Endpoints of toxicants in detention ponds	17							1
150	Integrate landscape architecture into overall stormwater management systems							1	1
151	Reduce directly connected impervious area							4	1
152	Reduce I/I in house service laterals								0
153	Improved I/I control in sanitary and storm sewers								0
154	Sewer maintenance optimization								0
									0

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Table 8–2. List of Priority Projects

Section	*Topic*
3.0	**Source characterization**
3.2	Urban land surfaces and land use
3.3	Fate and transport processes
4.0	**Receiving water impacts**
4.1.2	Rivers, lakes, estuaries, and wetlands
4.1.3	Nutrient, metal, and toxicant cycling
4.1.4	Biomonitoring
4.1.5	Benthic/sediment impacts
4.1.6	Land use/urbanization
4.2.1	Wet weather–groundwater–vadose zone interactions
4.3.1	Ecosystem risk/human health risks
5.0	**Management**
5.1	Organizational structure
5.2	Models and decision support systems
5.2.2	Enhancements in existing models
5.2.2.1	Graphical user interface/object oriented programming
5.2.2.2	Improvements in the analysis of rainfall input data
5.2.2.3	Improved parameter estimation techniques
5.2.2.4	Data centered approaches to enhancing stormwater modeling
5.2.2.4.1	Real-time control
5.2.2.4.2	Stochastic simulation
5.2.2.4.3	Neural networks
5.2.2.4.4	Calibration of transport models using improved databases
5.2.2.5	Linking surface phenomena
5.2.2.6	Linking with atmospheric models
5.2.2.7	Solids handling capability/sewer system modeling
5.2.3	Integrated decision support systems
5.2.3.3	Integrated GIS to refine spatial analysis capabilities
5.2.3.4	Interface simulation and optimization models
5.2.3.5	Integrated DSS for overall watershed
5.2.3.5.1	Watershed models
5.2.3.5.2	Ecosystem models
5.2.3.6	Risk management methodologies
5.3	Watershed management linkages
5.32	Watershed assessment methodology
5.3.3	Long-term watershed case studies
5.3.4	Urban research catchment network
5.3.5	Watershed-based water quality standards

Table 8–2, cont. List of Priority Projects

Section	*Topic*
6.0	**Regulatory policies and financial aspects**
6.1	Regulations and permits
6.1.2	Preparing effecive and implementable NPS watershed goals
6.1.3	Areas where regulatory flexibility can achieve watershed goals
6.2	Reuse and water resources
6.2	Financing and cost analysis
6.3.2	Methods of financing
6.3.3	Methods of cost allocation
6.3.4	Development of cost/performance data for controls
6.4	Benefits of urban stormwater management
6.4.2	Contingent valuation
6.4.3	CSO measures of success
6.5	Education and outreach
6.5.2	Public involvement, participation techniques
6.5.3	Coordination or stormwater research across agencies
7.0	**Controls**
7.1	On-site controls
7.1.2	Swales
7.1.3	Modifying urban surfaces
7.1.4	Reducing I/I from laterals
7.1.5	Design improvements for micro-storms
7.1.6	Stormwater reuse
7.1.7	Storm inlet devices
7.1.8	Industrial runoff control
7.1.9	Reuse of runoff as cooling water
7.2	Collection systems
7.2.2	Instrumentation and monitoring
7.2.3	Deposition and scour in sewers
7.2.4	Use of simulation models
7.2.5	Rehabilitation of sewers
7.2.6	Improved I/I control
7.2.7	Sewer maintenance effectiveness
7.2.8	Sewer and sedimentation tank flushing
7.2.9	Innovative design of sewers
7.3	Storage-treatment
7.3.2	Sanitary sewer overflows

Table 8–2, cont. List of Priority Projects

Section	*Topic*
7.3.3	High-rate operation of WWTP
7.3.4	High-rate treatment-vortex separators
7.3.5	High-rate treatment-disinfection
7.3.6	High-rate CSO treatment-magnetic and chemical additives
7.3.7	Control of solids
7.3.8	Toxics and metals
7.3.9	Wetlands and land disposal
7.3.10	BMP effectiveness

8.6 Sources and Monitoring

8.6.1 Automotive Pollution Source Reduction or Elimination

Cross-cutting research should be done by product, e.g., automobile, as well as by constituent, e.g., zinc, in order to understand how these constituents originate and move through urban systems. Among the many products and activities that affect urban WWFs, the automobile stands out as the most important generator of runoff. Much of the imperviousness in cities— streets, parking lots, driveways, garage and carport roofs—supports automobile-related activities. Also, automobiles generate a significant portion of the WWF pollutant load. An evaluation of WWF pollutant control opportunities by preventive methods associated with the automobile is recommended. This could be a major thrust area and would include not only pollutant load generation but also the feasibility of large-scale use of permeable and porous pavements. Lastly, the potential value of demand management techniques to reduce automobile dependency could be evaluated.

8.6.2 Source Control of Heavy Metals

Another major thrust area is to select a heavy metal and perform a source-prevention analysis with regard to urban WWFs. Heavy metals present a quandary whether they end up in sewage sludge, sediments in ponds and receiving waters, in soil, or groundwater. A vision for source management is that additional research will permit the gradual reduction or elimination of these urban WWF sources before they enter the system. This preventive approach is the preferred long-term, sustainable choice. US EPA has an active pollution prevention program; the WWF group of US EPA should explore joint funding opportunities.

Table 8–3. Final List of Projects by Priority

Topic	*Priority*	
Sources and Monitoring		
Automotive pollutant source reduction or elimination	1	
Source control of heavy metals		2
Innovative monitoring methods	1	
Receiving Water Impacts		
Improved understanding of the physical, chemical, and biological processes		2
Defining beneficial uses for urban receiving waters		2
Urban stream and sediment geomorphology and restoration	1	
Stormwater-groundwater-vadose zone impacts		2
Other Impacts		
Evaluation of other performance measures for wet weather flow systems	1	
Management		
Opportunities for decentralized urban wet weather management	1	
Restructuring federal water agencies to better address urban water issues		2
Models and decision support systems		
Improve SWMM to include all aspects of contemporary decision support systems	1	
Incorporate real-time control into decision support systems	1	
Watershed Management Linkages		
Participate in integrated long-term experimental evaluation of urban watersheds	1	
Regulatory policies and financial aspects		
Determine areas where regulatory flexibility can achieve watershed goals		2
Innovative financing mechanisms for wet weather controls		2
Improved methods for evaluating the effectiveness of public education		2
Source Controls		
Feasibility of aggressive on-site and local infiltration of wet weather flows	1	
Feasibility of using porous and permable pavements		2
Feasibility of reusing wet weather flows for irrigation	1	
Collection System Controls		
Evaluation of role of separate and combined sewers including storage in sewers	1	
Deposition and scour in sewers		2
Improved infiltration/inflow control methods	1	
Benefits of sewer flow and quality monitoring		2
Storage and Treatment		
Improved high-rate wet weather storage treatment devices	1	
High-rate operation of wastewater treatment plants	1	
Effectiveness of best management practices	1	
TOTAL	15	11

8.6.3 Innovative Monitoring Methods

Monitoring continues to be an issue because of difficulties in getting accurate data under the complex dynamic conditions that occur during wet weather periods. A strong theme of future WWF management strategies is to move toward data-centered modeling. Direct measurements are fundamental to understanding these complex processes. The regulatory process must promote continuous monitoring activities to determine what actually happens as WWFs move through urban areas. Recent hardware and software improvements make it much more cost effective to monitor performance directly and to use this information for real-time control. In spite of these advances, fundamental data on how wet weather processes occur in urban areas remain lacking.

8.7 Receiving Water Impacts

From the early days of WWF research, the chronic question has been, "What's the problem?" Efforts to demonstrate clear cause-and-effect linkages between WWFs and receiving water problems did not yield clear evidence (Heaney and Huber, 1984). Several reasons may be cited for this difficulty including:

- No significant acute receiving water impacts occur, only chronic long-term impacts;
- Urban WWF impacts are masked by all of the other impacts including sewage effluents, upstream pollution, non-urban nonpoint pollution, and hydrologic modifications;
- Lack of studies that concurrently measure landside and receiving water fluxes; and
- Lack of agreement on how to define "impacts". Are they violations of water quality standards, impaired beneficial uses, geomorphologic changes in the receiving water, etc.?

Debate on these issues continues. Participants at a 1996 Engineering Foundation Conference that focused on receiving water impacts could not agree on how to measure receiving water impacts in a way that was acceptable to the scientific, engineering, regulatory, and user communities (Roesner, 1997). Roesner (1997) summarizes the current situation:

> What became clear to this engineer during the course of the conference is that engineers view habitat degradation and restoration much differently than does the

scientific community. Engineers, being concerned and trained to protect the public health and safety of the community from flood damages, tend to design systems with a high degree of integrity that will withstand the 100-year flood. This has resulted in channel straightening, lined channels, removal of vegetation, and debris removal that are detrimental to the resident aquatic ecology. Scientists on the other hand advocate the use of many techniques for aquatic habitat restoration that cannot withstand the forces of flood flows and thus pose a distinct threat to public health and safety. What is required is the development of soft engineering that simultaneously provides for drainage and flood protection, achieves the scientists' criteria for ecosystem protection or restoration, and looks and acts like the natural environment. The conference shows that there are a number of issues that need to be addressed to make this happen.

8.7.1 Physical, Chemical, and Biological Responses in Receiving Waters

Research concerns in this category are long-standing and include efforts to define "natural" conditions as a baseline, looking for an overall index or set of indices to measure receiving water impacts, and developing criteria for receiving water impacts. The inherent complexity of receiving water systems makes it essential to continue to seek a better understanding of the physical, chemical, and biological processes. However, other measures of effect must be explored.

8.7.2 Defining Beneficial Uses for Urban Receiving Waters

A fundamental unresolved issue is to unambiguously define "receiving water." Many, if not most, of the surface waters in urban areas have been severely modified by human activities. Indeed, many of these receiving waters are artificial canals and ponds that were constructed for a variety of purposes. Because the most severe impacts of urban runoff tend to manifest themselves in these smaller receiving waters, their water quality protection often dictates the required level of control to meet existing regulations. It is probably futile to use "natural conditions" as a benchmark for urban receiving waters since many of them have been severely modified for a variety of human uses including water supply, flood control, navigation, hydropower, wastewater transport, mining, and agriculture. A more meaningful goal may be to develop a consensus on the future vision for that water and then to design a management program accordingly. Case studies of river and lake rejuvenation can be used to illustrate this concept.

8.7.3 Urban Stream and Sediment Geomorphology and Restoration

Research and regulation on receiving waters has tended to focus on impacts measured in the water column. Sediments are considered as sources or as sinks relative to the water column. Many of the long-term effects of WWFs and other pollutant sources are manifested in buildup of pollutants such as toxics in sediments. Serious impacts can occur if and when this sediment is resuspended. The dynamics of sediment deposition and resuspension are complex and site specific. Thus, it is a challenging research area. An important research need is to demonstrate the cost-effectiveness of managing receiving-water sediment as part of control programs. Without managing sediments, we ignore perhaps the most important component of receiving water impacts.

A newer emphasis in receiving-water evaluations is to use physical change in the receiving water as a measure of effect. These impacts are especially noticeable in smaller urban streams. Urbanization causes a flashier hydrologic response into receiving waters, and tends to reduce groundwater levels that are essential to provide base flows in streams. Thus, physical changes in the stream can be used as indicators of impacts. Research is needed to better quantify these impacts including the effects of wet weather detention systems on stream and sediment dynamics.

8.7.4 Wet Weather–Groundwater–Vadose Zone Impacts

Interest in subsurface WWF impacts on the vadose and groundwater zones is relatively recent in the United States. International research has given these effects more emphasis, especially in Europe and Japan, because of their extensive use of infiltration systems as WWF controls. With the expected growth of interest in decentralized management of WWF in the United States, the need to better understand and model subsurface effect is apparent. The influence of urban irrigation on local water budgets must be included because irrigation has a significant effect on antecedent conditions in many areas.

8.8 Other Impacts

Recently developed multiple performance measures for WWF control systems—e.g., the Association of Metropolitan Sewerage Agencies' list of 24 elements—illustrate the need to expand the evaluation beyond the traditional concern with meeting water quality standards. Little definitive evidence shows that urban WWFs can seriously impair human and ecosystem health. Because of the dynamic nature of WWFs, it is quite difficult to perform the necessary risk assessments to evaluate public health problems. The problem of evaluating ecosystem health impacts is even more complex because of the lack of clear definition of terms with regard to what is meant by ecosystem health. A significant component of integrated impact analysis is the socioeconomic and financial effects. This subject has received little attention with regard to WWF water quality problems. Quantification of direct—e.g., degraded property values—and indirect—e.g., non-user values—economic impacts can be a significant portion of the overall evaluation. Numerous "success" stories of stream and lake rejuvenation are reported in the literature. These successes can be measured by the economic and social revitalization in neighborhoods and cities as once polluted and otherwise degraded surface waters become improved to the point where they are viewed as assets to the community and become a focal point of redevelopment efforts.

8.9 Management

8.9.1 Opportunities for Decentralized Wet Weather Management

The literature on sustainable urban systems strongly suggests the need to manage wet weather problems using decentralized systems with strong emphasis on local infiltration, detention, and reuse. The development of decentralized WWF systems would represent a shift away from the prevailing tendency to use large centralized controls. Decentralized WWF systems are most cost-effective if water, wastewater, and wet weather management functions are integrated at this local spatial scale. International efforts in this area should be reviewed as part of this research initiative.

8.9.2 Restructuring Federal Water Agencies to Better Address Urban Water Issues

Wet weather flow quality regulatory programs of the past 25 years have emanated primarily from the federal government. During the same period, urban wet weather utilities have been created in many cities and several metropolitan areas. Many of these agencies have quantity management as their primary, and often exclusive, mandate. Also, watershed-based organizations are emerging. It is too early to predict the influence of these organizations. Another new organizational concept is privatization of these activities as has been done internationally. The most radical departure from current U.S. organizational practice would be to decentralize current federal responsibilities down to state, local, and watershed levels. Aggressive movements in this direction have been made in Great Britain, Australia, and New Zealand. These decentralized organizations are typically watershed-based and handle all aspects of water. Thus, they are in a much better position to develop and finance multi-purpose programs. Federal wet weather flow management responsibilities in the United States are spread across several federal agencies with numerous, and often conflicting, mandates, e.g., to promote economic development vs. to protect the environment. Is it desirable to modify the missions of these agencies so that WWFs can be managed more consistently?

8.10 Models and Decision Support Systems

8.10.1 Improve Stormwater Management Model to Include All Aspects of Contemporary Decision Support Systems

US EPA support of the development of the US EPA Stormwater Management Model (SWMM) has resulted in major benefits in terms of improved methods of analysis of urban WWF problems. Developed around 1970, SWMM has been improved so it can now handle a wide variety of hydraulic boundary conditions. Contemporary users have come to expect a user-friendly environment, nice graphics, links to database management systems, links to real-time control, links to GIS, and seamless integration across modules, i.e., from runoff to transport to storage/treatment to receiving water. Also, they would like to link the simulators to optimizers that can help find good, if not optimal, solutions. Other desirable features include explicit considerations of uncertainty, and a benefit/cost element to evaluate the desirability of various alternatives. Lastly, linkages are desired between WWFs and urban water supply, wastewater collection and treatment systems, flood control, hydropower, and other aspects of water management so that an integrated view can be taken of urban watershed management.

Lacking continuous federal support during the past 15 years, SWMM has not kept pace with other, more recent, models such as MOUSE in terms of some technical capabilities—e.g., solids in sewers, real-time control—but more obvious is its comparatively unfriendly user interfaces. Commercial products such as XP SWMM offer much easier to use shells for running SWMM. Research is needed to develop a vision of SWMM for the 21st century that addresses key questions, such as whether US EPA should support a major development effort, whether SWMM should remain non-proprietary, and what new features are needed in the model.

8.10.2 Incorporate Real-Time Control into Decision Support Systems

Real-time control (RTC) provides an important overarching framework for future decision support system development. Ultimately, system performance should be measured directly and intelligent decisions made accordingly. Intensified research is needed in the United States to inventory the current status of using RTC, especially internationally, and then to develop innovative improved RTC techniques for WWFs.

8.11 Watershed Management Linkages

In spite of tremendous interest in the 1990s to use watershed-based approaches for evaluating urban water problems, little research has been done on methods for doing such evaluations. The notable exception is the US EPA/NSF/USDA program on watershed research, active for the past four years. More formal linkages to this program should be explored.

One striking gap in understanding urban water management is the absence of long-term experimental urban watersheds that can directly assess the impacts of urbanization. A possible initiative is to tie to the recently funded NSF Long-Term Ecological Research (LTER) urban watersheds efforts, for instance in Baltimore.

8.12 Regulatory Policies and Financial Aspects

8.12.1 Determine Areas Where Regulatory Flexibility Can Achieve Watershed Goals

During recent years, US EPA has been trying to offer more flexibility in its regulatory programs in order to achieve more cost-effective WWF programs (Lindsey, Swietlik, and Hall, 1996). Opportunities for more cost-effective programs include allowing multi-media analysis to see where pollutants can be more effectively controlled or eliminated at the source, allowing upstream and downstream trade-offs for control of a specific constituent of concern such as nutrients or allowing trade-offs with other water management activities, for example, changing the operation of a hydropower reservoir. As the GAO (1997) evaluation of these new regulatory thrusts points out, US EPA faces major challenges to make significant changes in the way it has done business for the past 25 years. Research is needed to evaluate the effectiveness of experimental programs to provide more regulatory flexibility.

8.12.2 Innovative Financing Mechanisms for Wet Weather Controls

During the early years of US EPA, financing of WWF control programs was relatively uncomplicated since the federal government had both the carrot and the stick. The carrot was very generous federal cost sharing for control projects. The 1990s brought a different financial situation with the federal government still wielding the stick of regulations but without a significantly smaller carrot in the form of financial incentives to pay the costs. The much ballyhooed watershed and integrative water management programs require sophisticated cost-sharing arrangements, a major hurdle. Research is needed on how to obtain sustainable financing to support these potentially expensive programs.

A significant constraint on developing innovative urban stormwater management programs is the fragmented funding policies of the federal agencies, the largest supporters of wet weather research. Under current funding patterns, it is difficult to take a holistic view of the problem because research funding is available only to evaluate specified components of the problem. It is hard to be optimistic about the prospects for cooperatively supported integrative research from our assertively independent federal water agencies—US EPA, the Corps of Engineers, FEMA, USDA, FHWA, USGS, NOAA, DOE, DoD, and other agencies.

8.12.3 Improved Methods for Evaluating the Effectiveness of Public Education

While education is an essential element in improved environmental management, it is difficult to quantify the cause-and-effect linkages without longer-term data collection. Litter control continues to be cited as a priority research need. Experience in evaluating the effectiveness of water conservation programs should be evaluated as a case study of related efforts to quantify the effectiveness of educational programs.

8.13 Source Controls

8.13.1 Feasibility of Aggressive On-Site and Local Infiltration of Wet Weather Flows

During the past decade demand-side management has taken hold in the water resources and related energy fields. Correspondingly, in the water quality field, attention has switched from end-of-pipe treatment of the unwanted by-products of urbanization to reducing the load entering the city through demand management. Water conservation efforts significantly influence the quantity and quality of domestic wastewaters. Also, local management of WWFs by infiltration and storage reduces the downstream load. Research is needed on the value of demand-management approaches and their long-term impacts; for example, will local infiltration of WWFs and using gray water for lawn watering cause public health problems?

Many innovative research areas have been suggested under the general category of on-site control. The most fundamental and sustainable approach is to reduce or eliminate the size of the problem at the source by preventive measures. With successful experience in Europe and Japan, interest in local infiltration systems is growing in the United States. These infiltration systems can provide local control that mimics the performance of the undisturbed natural system. Research to date indicates that these infiltration systems are safe if the infiltrated water comes from low-risk sources such as rooftops, residential driveways, and seldom-used parking areas. WWF can also be used for gray water in houses. Adequate monitoring is essential to properly evaluate the efficacy of on-site controls. Such monitoring should include the effect of lawn watering on the local water budget.

8.13.2 Feasibility of Using Porous and Permeable Pavements

The feasibility of using porous and permeable pavements, especially in low traffic areas, should be explored with a combination of laboratory, pilot, and full-scale monitoring systems. This significant effort should be coordinated with U.S. transportation agencies and international programs that have already established testing facilities.

8.13.3 Feasibility of Using Wet Weather Flows for Irrigation

A related area of on-site control is to reuse WWFs for local irrigation. This WWF can be stored on-site in cisterns or in neighborhood surface ponds. The option may be very attractive in areas with high irrigation demands and expensive water treatment costs. With lawn watering as a beneficial use, the economics of using large regional ponds vs. local ponds may switch to favor local ponds to reduce distribution system costs.

8.14 Collection System Controls

8.14.1 Role of Separate and Combined Sewers Including Storage in Sewers

The pros and cons of combined vs. separate sewer systems and fundamental design criteria continue to be debated; see for instance, "Two feet per second ain't even close" (Shafer, 1994). Research is needed to improve bases for design. Innovative options to be evaluated include oversizing sewers as a low-cost source of storage; and the inclusion of flushing systems as an integral part of sewer systems in order to optimize solids management. Sewer flow and quality measurements are essential to improve the state of art.

8.14.2 Deposition and Scour in Sewers

Existing simulation models can predict the behavior of WWF quantity in collection systems. However, they are much less adept at predicting water quality because of a high degree of uncertainty on the spatial and temporal variability in the quality of stormwater entering the sewers, and the complex sediment deposition and resuspension that occurs within the collection systems. Another long-standing gap in knowledge is understanding the nature of infiltration and inflow. The recently completed European initiative, entitled "Solids in Sewers" (Ashley, 1996), provides a prototype for future research programs organized to address these complex questions.

8.14.3 Improved Infiltration/Inflow Control Methods

Improved methods of I/I evaluation and control must be developed. Existing sewer design and construction practices still allow significant I/I to enter sewers. Innovative I/I controls for existing sewers are also needed. Current high levels of I/I are wasting valuable capacity in WWTPs.

8.14.4 Sewer Flow and Quality Monitoring

Professional and regulatory communities need to be convinced of the fundamental need to measure flows and quality in collection systems. A useful research project would be to document the benefits from such monitoring. A significant number of case studies have accumulated during a 30 year history of using real time control (RTC) to enhance the use of storage in combined sewer systems. The value of measurements as an integral component of RTC can be quantified from retrospective case studies.

8.15 Storage/Treatment

8.15.1 High-Rate Wet Weather Storage Treatment Devices

A wide variety of high-rate, wet weather treatment devices were developed and tested in the 1970s as part of an US EPA WWF research and demonstration program. This program supported a balance of laboratory and pilot plant testing of innovative technologies. It also provided support for demonstration projects and widely disseminated the results of these tests. Unfortunately, this program was sharply curtailed and much of this information is now obsolete and should be updated.

8.15.2 High-Rate Operation of Wastewater Treatment Plants

An important area requiring additional research is optimal operation of conventional wastewater treatment plants (WWTPs) in response to wet weather conditions. A significant reduction in sanitary sewer and combined sewer overflows could be achieved with high-rate operation of WWTPs during and following wet weather events. This is currently an active research area in Europe.

8.15.3 Effectiveness of Best Management Practices

The effectiveness of BMPs including ponds and wetlands continues to be debated. Even now, few experimental studies properly collect data to determine the overall effectiveness of these devices. A cursory look at the scientific basis underlying the widely reported "typical removal rates" in the literature reveals that we are on shaky ground. An important general research and technology transfer need is to develop a statistically meaningful database on actual performance of these BMPs that could be used in a systematic way to improve the state of the art.

8.16 Estimated Cost of U.S. WWF R&D Program

In the United States, research on urban runoff quantity and quality has been undertaken since the late 1960s, initial interest focusing on the problem of combined sewer overflows. The US EPA Municipal Environmental Research Laboratory's Storm and Combined Sewer Program invested $60 million to $70 million in some 250 extramural projects up to 1981. The US EPA Nationwide Urban Runoff Program (NURP) sponsored $30 million in field studies in 28 cities between 1979 and 1983. Also, other federal agencies including the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the Office of Water Research and Technology had active urban WWF research and demonstration programs during the 1970s. While the exact total is uncertain, the federal investment in WWF research before 1983 probably exceeded $100 million (Heaney, 1986).

Roesner and Traina (1994) cite the American Public Works Association (1992) estimates of urban WWF control costs in the United States ranging from $147 million to $407 billion in capital costs and $1.2 billion to $542 billion/year in annual O&M costs depending upon the assumed level of BMP control. This extreme variation in the cost estimates reflects the high degree of uncertainty regarding future wet weather regulations. According to the 1996 US EPA Clean Water Needs Survey (CWNS), a total of $139.5 billion of capital cost is needed to satisfy all program categories eligible for state revolving funding for the design year (2016) population (U.S EPA, 1997).

Operation and maintenance costs are not included in this total. The breakdown of these total costs is shown in Table 8–4.

The only wet weather flow category comprehensively addressed in the 1996 CWNS is combined sewer overflows with a total capital need of $44.7 billion. According to US EPA (1997), sanitary sewer overflow control costs are probably underestimated in the 1996 CWNS:

> Although SO needs are not identified separately in the CWNS, some associated costs to address SO problems are included in Categories I, III, and IV. In general, EPA believes that the needs estimates in these categories related to SSOs underestimates the total costs associated with preventing SSOs. Therefore, the scale of the SO problem is currently being addressed by EPA separately from the CWNS.

In addition to excluding SSOs, the 1996 CWNS does not address control of urban runoff from storm sewers.

A conservative estimate of the expected capital costs for CSOs, SSOs, and stormwater quality management is about $100 billion. The expected amortized annual value of this capital investment is about $10 billion per year. Annual operation and maintenance costs would be comparable in size yielding an expected total annual cost of $20 billion per year.

The expected cost of managing wet weather flows can be used to estimate the needed expenditures for research and development to attempt to minimize these costs. A rule of thumb for the desired level of R&D is that it range from 2 to 6% of the investment depending on the type of technology. However, lack of funding during the past 15 years will require a few years to rebuild the necessary research infrastructure within US EPA and the university and professional research communities. Significant research efforts have been underway in Europe, Australia, Japan, and other counties during the past 15 years. Thus, we should look abroad to accurately assess the current state of the art. Using a conservative estimate of 1 to 2% R&D needed to support this WWF program yields an annual research funding need of $20 million to $40 million per year for the U.S. WWF program. Programs for international cooperation in research should be explored as a way to develop the most cost-effective R&D programs.

Table 8–4. Needs for Publicly Owned Wastewater Treatment Facilities and Other Eligibilities (US EPA, 1997)

Need Category	*Project Description*	*Total Capital Needs, $ billion*
Title II Eligible Projects		
I	Secondary Treatment	26.5
II	Advanced Treatment	17.5
III	Infiltration/Inflow Correction	3.3
IV	Sewer Replacement/Rehabilitation	7
V	New Collector Systems	10.8
VI	New Interceptor Sewers	10.8
V	Combined Sewer Overflows	44.7
VI	Stormwater	7.4
Total Categories I through VI		128
Other Eligible Projects (Sections 319 and 320)		
VIIA-C	Nonpoint Sources (agriculture and silviculture only)	9.4
VIID	Urban Runoff	1
VIIE-G	Groundwater, Estuaries, Wetlands	1.1
Total Categories VII		11.5
Grand Total		139.5

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WATERSHED MANAGEMENT

Residential and Commercial Source Control Programs to Meet Water Quality Goals

SOURCE CONTROL

PROJECT 95-IRM-1

Water Environment Research Foundation

1998

ABSTRACT

A nationwide literature assessment was conducted to collect information on residential and commercial sources of wastewater and stormwater pollution. In most parts of the country, industrial sources of pollution have been effectively controlled through established pretreatment and industrial stormwater programs. To achieve further reductions in pollutant levels, communities are increasingly looking to nontraditional—commercial and residential—sources of pollutants.

The project team gathered information from around the country concerning wastewater and stormwater pollution prevention and public education programs that have been developed to address non-industrial sources. This research will provide a valuable resource for communities developing wastewater and stormwater pollution prevention programs. Also described herein are monitoring studies conducted to identify wastewater and stormwater pollutants and their sources. The report covers best management practices and program ideas for specific sources of pollutants. Public education programs and efforts to measure program effectiveness are also discussed. In addition, the report provides a list of program representatives who can be contacted for additional information on specific programs. Based on the results of the assessment, future research needs with respect to commercial and residential sources are identified.

WATER ENVIRONMENT RESEARCH FOUNDATION

RESIDENTIAL AND COMMERCIAL SOURCE CONTROL PROGRAMS TO MEET WATER QUALITY GOALS

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by

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BENEFITS

- Provides a valuable resource for communities developing wastewater and stormwater pollution prevention programs;
- Cites monitoring studies that identified wastewater and stormwater pollutants and their sources;
- Describes best management practices (BMPs) and program ideas for specific sources of pollutants;
- Identifies public education strategies, approaches to different audiences, and types of materials developed;
- Discusses ways to gauge program effectiveness;
- Lists program representatives who can provide additional information on specific programs; and
- Identifies future research and program development needs with respect to commercial and residential sources.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS III
BENEFITS V
LIST OF TABLES XV
LIST OF FIGURES XVII

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION

1.1 Background 1-1
1.2 Project Purpose 1-3
1.3 Project Methodology and Report Organization 1-3
1.4 Wastewater and Stormwater Pollution Prevention Programs in the United States 1-5
1.4.1 Region 1 1-5
1.4.2 Region 2 1-8
1.4.3 Region 3 1-9
1.4.4 Region 4 1-10
1.4.5 Region 5 1-11
1.4.6 Region 6 1-11
1.4.7 Region 7 1-12
1.4.8 Region 8 1-12
1.4.9 Region 9 1-13
1.4.10 Region 10 1-15
1.4.11 National Efforts 1-15

2.0 MONITORING AND SOURCE IDENTIFICATION

2.1 Receiving Water Monitoring 2-8
2.1.1 NY/NJ Harbor Estuary (Region 2) 2-8

TABLE OF CONTENTS, CONT.

2.1.2 Chesapeake Bay (Region 3) 2-10
2.1.3 San Francisco Bay (Region 9) 2-12
2.1.4 Santa Monica Bay (Region 9) 2-13
2.2 Stormwater Monitoring and Source Identification 2-15
2.2.1 General Stormwater Monitoring 2-15
2.2.2 Monitoring Programs by US EPA Region 2-20
2.2.2.1 NY/NJ Harbor (Region 2) 2-20
2.2.2.2 Chesapeake Bay (Region 3) 2-21
2.2.2.3 Wisconsin (Region 5) 2-22
2.2.2.4 Illinois (Region 5) 2-25
2.2.2.5 Lake Superior (Region 5) 2-25
2.2.2.6 Galveston Bay (Region 6) 2-27
2.2.2.7 Trinity River Basin—Dallas/Fort Worth (Region 6) 2-28
2.2.2.8 Austin (Region 6) 2-28
2.2.2.9 Iowa (Region 7) 2-29
2.2.2.10 Bay Area Management Agencies Association (Region 9) 2-29
2.2.2.11 Ventura County (Region 9) 2-30
2.2.2.12 Sacramento (Region 9) 2-31
2.2.2.13 Puget Sound (Region 10) 2-34
2.2.3 New Directions in Stormwater Monitoring 2-35
2.3 Monitoring and Source Identification 2-37
2.3.1 General Wastewater Monitoring 2-37
2.3.2 Monitoring Programs by US EPA Region 2-40
2.3.2.1 Narragansett Bay (Region 1) 2-40
2.3.2.2 NY/NJ Harbor (Region 2) 2-40
2.3.2.3 San Francisco Bay Area (Region 9) 2-41
2.3.2.4 City and County of San Francisco (Region 9) 2-43
2.3.2.5 Palo Alto (Region 9) 2-44
2.3.2.6 Novato (Region 9) 2-47
2.3.2.7 San Jose (Region 9) 2-47
2.3.2.8 Union Sanitary District (USD) (Region 9) 2-49
2.3.2.9 South Bayside System Authority (Region 9) 2-49
2.3.2.10 Central Contra Costa Sanitary District (CCCSD) (Region 9) 2-50

2.3.2.11 Hayward (Region 9) .2-51
2.3.2.12 Sunnyvale (Region 9) .2-52
2.3.2.13 Los Angeles (Region 9) .2-53
2.3.2.14 Orange County (Region 9) .2-54
2.3.2.15 Arizona (Region 9) .2-54
2.3.2.16 Washington (Region 10) .2-58

3.0 COMMERCIAL SOURCES OF POLLUTANTS

3.1 Approaches to Control of Commercial Sources 3-1
3.1.1 Permits 3-1
3.1.2 Zero Discharge Certification 3-2
3.1.3 Educational Outreach 3-2
3.1.3.1 Outreach Materials 3-2
3.1.4 Financial Incentives 3-3
3.1.5 Technical Assistance 3-4
3.1.5.1 Montana Pollution Prevention Program 3-5
3.1.5.2 Iowa Waste Reduction Center 3-5
3.1.6 Recognition Programs 3-6
3.1.6.1 Clean Bay Business Program 3-6
3.1.6.2 City of Santa Rosa 3-8
3.1.7 Training and Certification Programs 3-9
3.1.7.1 Consruction Certification Programs 3-9
3.1.7.2 Mobile Cleaners Certification Programs 3-10
3.2 Pollution Prevention Control Strategies for Specific Commercial Sources 3-11
3.3 Sources of Wastewater and Stormwater Pollutants 3-11
3.3.1 Vehicle Service Facilities 3-11
3.3.1.1 Other Vehicle-Related Activities 3-13
3.3.1.2 Best Management Practices 3-14
3.3.1.3 Program Elements 3-15
3.3.2 Restaurants and Food Service Businesses 3-19

TABLE OF CONTENTS, CONT.

3.3.2.1 Best Management Practices 3-19
3.3.2.2 Program Elements 3-20
3.3.3 Painting Contractors 3-22
3.3.3.1 Best Management Practices 3-22
3.3.3.2 Program Elements 3-22
3.4 Sources of Stormwater Pollutants 3-23
3.4.1 Construction 3-23
3.4.1.1 Best Management Practices 3-24
3.4.1.2 Program Elements 3-27
3.4.2 New Development 3-27
3.4.2.1 Best Management Practices 3-29
3.4.2.2 Program Elements 3-31
3.4.3 Boatyards/Marinas 3-32
3.4.3.1 Best Management Practices 3-33
3.4.3.2 Program Elements 3-34
3.4.4 Existing Development 3-36
3.4.4.1 Best Management Practices 3-36
3.4.4.2 Program Elements 3-36
3.4.5 Mobile Cleaners 3-37
3.4.5.1 Best Management Practices 3-37
3.4.5.2 Program Elements 3-38
3.4.6 Landscape Maintenance 3-39
3.4.7 Brake Pads 3-39
3.5 Sources of Wastewater Pollutants 3-41
3.5.1 Laboratories and Medical Facilities 3-41
3.5.1.1 Pollution Prevention for Mercury and Silver 3-41
3.5.1.2 Other Best Management Practices 3-42
3.5.1.3 Program Elements 3-43
3.5.2 Printers 3-44
3.5.2.1 Best Management Practices 3-45
3.5.2.2 Program Elements 3-46
3.5.3 Dentists 3-46
3.5.3.1 Best Management Practices 3-48

TABLE OF CONTENTS, CONT.

3.5.3.2 Program Elements 3–48
3.5.4 Photoprocessors 3–49
3.5.4.1 Best Management Practices 3–50
3.5.4.2 Program Elements 3–51
3.5.5 Jewelry Manufacturing 3–51
3.5.5.1 Best Management Practices 3–53
3.5.5.2 Program Elements 3–54
3.5.6 Cooling Water Systems 3–55
3.5.6.1 Best Management Practices 3–55
3.5.6.2 Program Elements 3–56
3.5.7 Machine Shops 3–56
3.5.7.1 Best Management Practices 3–57
3.5.7.2 Program Elements 3–58
3.5.8 Dry Cleaners 3–58
3.5.8.1 Best Management Practices 3–60
3.5.8.2 Program Elements 3–60
3.5.9 Ceramics 3–62
3.5.9.1 Best Management Practices 3–62
3.5.9.2 Program Elements 3–62
3.5.10 Wood Finishers 3–63
3.5.10.1 Best Management Practices 3–63
3.5.10.2 Program Elements 3–63

4.0 RESIDENTIAL SOURCES OF POLLUTANTS

4.1 Approaches to Residential Sources 4–1
4.1.1 Public Education 4–1
4.1.2 Technology-Based Strategies 4–2
4.1.3 Legislative Strategies 4–2
4.2 Specific Residential Sources of Pollutants 4–3
4.2.1 Household Plumbing Corrosion 4–3

TABLE OF CONTENTS, CONT.

4.2.2 Laundry Graywater 4–5

4.2.2.1 Graywater Systems 4–6

4.2.3 Pesticide Use and Landscape Maintenance 4–7

4.2.3.1 General Pesticide Use 4–7

4.2.3.2 Public Education Programs for Organophosphate Pesticides . . . 4–9

4.2.3.3 Landscape Maintenance 4–10

4.2.4 Vehicle Maintenance and Used Motor Oil 4–11

4.2.4.1 Used Motor Oil 4–12

4.2.4.2 Vehicle Maintenance and Car Washing 4–14

4.2.5 Home Painting Activities 4–15

4.2.6 Household Cleaners and Other Consumer Products 4–15

4.2.6.1 Green Cleaning Kit 4–17

4.2.7 Pools and Spas 4–18

4.2.8 Root Control Products 4–18

5.0 PUBLIC EDUCATION PROGRAMS

5.1 Stormwater and Pollution Prevention Messages 5–1

5.1.1 General Message Themes 5–2

5.1.2 Regional Flavor of Messages and Graphics 5–2

5.1.3 Specific Messages Used in Public Education Programs 5–3

5.1.3.1 Stormwater/Urban Runoff Public Education Messages 5–3

5.1.3.2 Common Messages for Wastewater Pollution Prevention Programs 5–6

5.1.4 Best Management Practices for the General Public 5–8

5.1.5 Messages Targeting Specific Sources for Wastewater 5–10

5.2 Audiences 5–11

5.2.1 The General Public 5–12

5.2.2 Ethnic Communities 5–13

5.2.3 Business Audiences 5–14

5.2.3.1 Point-of-Purchase 5–15

5.2.3.2 Business Recognition 5–15

TABLE OF CONTENTS, CONT.

5.2.3.3 Educational Materials for Businesses 5–16
5.2.3.4 Ethnic Employee Training 5–16
5.2.4 Municipal Audiences 5–17
5.2.5 School Programs and Children 5–18
5.3 Effective Strategies for Different Audiences and Messages 5–20
5.3.1 Media (Newspaper, Television, Radio) 5–21
5.3.2 Public Events 5–24
5.3.3 Workshops, Trade Shows 5–25
5.3.4 Videos 5–26
5.3.5 Course Curricula 5–28
5.3.6 Brochures, Pamphlets, and Other Written Materials 5–29
5.3.7 Advertisements, Promotional Items 5–30
5.4 Watershed Management/Stewardship Programs 5–30
5.4.1 Lake Superior Binational Program 5–31
5.4.2 National Cattlemen's Beef Association (NCBA) Water Quality Information Project 5–31
5.4.3 The Rouge River National Wet Weather Demonstration Project 5–31
5.4.4 St. Louis River Citizen Program 5–32
5.4.5 New York City Watershed Protection Program 5–32
5.4.6 King County Department of Natural Resources 5–32
5.4.7 Puget Sound Water Quality Authority (PSWQA) 5–33
5.5 Social Marketing/Behavior Change Principles 5–34

6.0 PROGRAM EFFECTIVENESS

6.1 Program Evaluation Using Various Indicators 6–2
6.1.1 Vehicle Service Facilities 6–3
6.1.2 Photoprocessing 6–3
6.1.3 Corrosion 6–4
6.1.4 Pesticide Use 6–4

R0025963

TABLE OF CONTENTS, CONT.

6.1.5 Financial Program Evaluation 6–5
6.2 Using Models to Predict Effectiveness 6–5
6.3 Surveys 6–6
6.3.1 General Awareness Surveys 6–10
6.3.2 Surveys that Measure Effectiveness of Campaigns 6–11

7.0 SUMMARY AND RECOMMENDATIONS

7.1 Summary 7–1
7.1.1 Monitoring and Source Identification 7–1
7.1.2 Commercial Sources of Pollutants 7–3
7.1.3 Residential Sources of Pollutants 7–5
7.1.4 Public Education Programs 7–7
7.1.5 Program Effectiveness 7–9
7.2 Recommendations 7–10
7.2.1 Future Research Topics 7–10
7.2.2 Assigning Priorities to Workshop Recommendations 7–16

APPENDIX A A–1
APPENDIX B B–1
APPENDIX C C–1
APPENDIX D D–1
APPENDIX E E–1
REFERENCES R–1
PUBLICATION ORDER FORM
WERF SUBSCRIBERS

LIST OF TABLES

ES-1 Summary of Pollutants Evaluated (Out of 48 Studies) ES-2
ES-2 Summary of Commercial and Residential Sources Evaluated ES-4
1-1 Regional Pollutant Evaluation 1-7
2-1 Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies 2-2
2-2 Water Column Concentration Ranges of Pollutants of Concern in Chesapeake Bay 2-11
2-3 Pollutant Impacts to Santa Monica Bay 2-14
2-4 Summary of Pollutants Detected in Stormwater Based on NURP Results 2-16
2-5 Mean Concentrations in Stormwater Samples (Non-Filtered/Filtered) 2-19
2-6 Stormwater Runoff Data for Madison, Wisconsin 1993-94 2-24
2-7 Contaminant Concentrations in Stormwater Samples Collected from Lake Superior Basin Cities 2-26
2-8 Major Potential Nonpoint Sources of Pollutants to Galveston Bay Watershed . . 2-27
2-9 Median EMCs Based on 1994-95 Wet Weather Monitoring Data Collected in Ventura County, California 2-32
2-10 Pesticide Concentrations Detected in Surface Water of Puget Sound Drainages 2-35
2-11 Stormwater Indicator Profile Categories 2-38
2-12 Pollutants Attributed to Specific Commercial Facilities 2-39
2-13 Copper Concentrations from Various Sources Based on Data from California POTWs 2-42
2-14 Summary of Copper and Nickel Monitoring Data from Commercial Businesses (Data Obtained from Surveyed POTWs) 2-48
2-15 Commercial and Residential Sources of Inorganic Pollutants as Reported by South Bayside System Authority 2-50
2-16 Sources of Diazinon and Chlorpyrifos 2-51
2-17 City of Sunnyvale WPCP 1995 Source Loadings of Copper and Nickel by Source Category 2-53
2-18 Concentrations of Pollutants in Domestic Wastewater for the County Sanitation Districts of Orange County 2-55

LIST OF TABLES, CONT.

3-1	Business Assistance Centers	3-4
3-2	Business Recognition and Certification Programs	3-7
3-3	Pollutants Associated with Commercial Sources	3-12
3-4	Information Collected for Vehicle Service Facilities	3-17
3-5	Information Collected for Food Service Businesses	3-21
3-6	Information Collected for Painting Activities	3-23
3-7	Information Collected for Construction Activities	3-28
3-8	Information Collected for New Development	3-32
3-9	Information Collected for Boatyards/Marinas	3-35
3-10	Information Collected for Existing Development	3-36
3-11	Information Collected for Mobile Cleaners	3-38
3-12	Information Collected for Landscape Maintenance	3-40
3-13	Information Collected for Hospitals and Laboratories	3-43
3-14	Printing Process Characteristics	3-44
3-15	Information Collected for Commercial Printers	3-47
3-16	Information Collected for Dental Facilities	3-50
3-17	Information Collected for Photoprocessors	3-52
3-18	Information Collected for Jewelry Manufacturers	3-54
3-19	Information Collected for Cooling Water Systems	3-57
3-20	Information Collected for Machine Shops	3-59
3-21	Information Collected for Drycleaners	3-61
3-22	Information Collected for Ceramics Studios	3-63
3-23	Information Collected for Wood Finishers	3-64
4-1	Pollutants Associated with Residential Activities	4-3
4-2	Information Collected on Landscape Maintenance and Pesticide Use	4-13
6-1	Examples of Program Effectiveness of Local Source Control Programs	6-2
6-2	Public Education Surveys	6-7
7-1	Summary of Pollutants Evaluated	7-2
7-2	Pollutants Associated with Commercial Sources	7-4
7-3	Pollutants Associated with Residential Activities	7-6
C-1	Summary of Additional Monitoring and Source Identification Studies	C-3
D-1	Summary of Regions in United States that Provided Public Education Materials for WERF Study	D-3

LIST OF FIGURES

1-1 US EPA Regions 1-6

R0025967

EXECUTIVE SUMMARY

A nationwide assessment was conducted to collect information on residential and commercial sources of wastewater and stormwater pollution. In most parts of the country, industrial sources of pollution have been effectively controlled through established pretreatment and industrial stormwater programs. To achieve further reductions in pollutant levels, communities are increasingly looking to nontraditional pollution sources (i.e., commercial and residential sources).

The project team gathered information from around the country concerning wastewater and stormwater pollution prevention and public education programs that have been developed to address non-industrial sources. This research will provide a valuable resource for communities developing wastewater and stormwater pollution prevention programs. Monitoring studies conducted to identify wastewater and stormwater pollutants and their sources are described in this report. Descriptions of best management practices (BMPs) and program ideas for specific sources of pollutants are included. Public education programs and efforts to measure program effectiveness are also discussed. In addition, the report provides a list of program representatives who may be contacted for additional information on specific programs. Based on the results of the assessment, future research needs with respect to commercial and residential sources are identified.

Over 200 people from wastewater, stormwater, and industrial pretreatment programs around the country provided information on pollution prevention activities being conducted in 25 states representing all ten regions of the United States Environmental Protection Agency. Findings are organized into the following areas:

- Monitoring and source identification efforts;
- Commercial and residential sources of pollutants;
- Public education programs; and
- Measurements of program effectiveness

Monitoring and Source Identification Studies

The pollutants evaluated during the review of monitoring and source identification studies are listed in Table ES-1. Metals were found to be the most commonly studied pollutants in the wastewater and stormwater studies reviewed for this assessment. Numerous studies have also evaluated levels of conventional pollutants and of nutrients. Pesticides and their sources were seen to be emerging as an area of more recent interest and activity. Fewer studies targeted organic pollutants (other than pesticides) and their sources.

Table ES-1. Summary of Pollutants Evaluated (Out of 48 Studies)

Category	Number of Studies	Pollutants Most Commonly Evaluated
Metals	36	Cu, Hg, Ni, Pb, Zn
Pesticides	14	chlorpyrifos, diazinon
Organics	13	polyaromatic hydrocarbons (PAHs), solvents, hydrocarbons
Nutrients	10	phosphorus, ammonia
Conventional	9	biochemical oxygen demand (BOD), total suspended solids (TSS), oil and grease
Others	5	cyanide, tributyltin

With respect to source identification, several studies have been conducted that evaluate wastewater or stormwater run-off from commercial or residential areas. However, few of these studies identify specific sources (e.g., individual businesses, specific residential activities) within the commercial or residential area. Studies that have investigated specific commercial businesses or residential activities have focused on evaluating operations and materials used rather than sampling wastewater or runoff. In most cases, the difficulty in obtaining representative wastewater or run-off samples from small businesses or residences hampered sampling efforts.

In addition to traditional monitoring efforts, new directions in stormwater monitoring were identified, including special studies, volunteer monitoring programs, and incorporation of environmental indicators into monitoring strategies.

Commercial and Residential Sources of Water Pollution

Several commercial sources of pollutants have been targeted by pollution prevention and stormwater programs around the country as shown in Table ES-2. Strategies that have been developed to address these sources include permitting, educational outreach, recognition programs, certification programs, and business assistance centers.

Many programs, all over the country, have developed programs for vehicle service facilities, construction activities, and food service businesses because most communities have several businesses that fall into these categories, and these businesses are subject to multiple regulatory programs (e.g., wastewater, stormwater, air quality, hazardous materials, health services, etc.).

Efforts have also been directed toward printers, painting contractors, dentists, laboratories, medical facilities, photoprocessors, landscape maintenance, dry cleaners, and machine shops. It should be noted that some of the programs addressing printers, dry cleaners and machine shops focus more on air emissions and hazardous materials generation than wastewater issues. Sources for which little work has been done include brake pads, existing development, new development, vehicle related activities, wood finishers, jewelry manufacturers, mobile cleaners, cooling water systems, and ceramics studios.

Residential sources of wastewater and stormwater pollution are less often the focus of outreach efforts as shown in Table ES–2. Most of the residential source programs focus on household cleaners and landscape maintenance. In most cases, landscape maintenance outreach targets general practices as opposed to specific products. With respect to household cleaners, much of the outreach targets products that have been determined to be of little concern to wastewater.

A moderate amount of work has been done to address water supply corrosion and home vehicle maintenance. Effective source control for corrosion has involved water purveyors to reduce the corrosivity of the water supply.

Table ES-2. Summary of Commercial and Residential Sources Evaluated

Source	Wastewater/ Stormwater	Number of Programs
Commercial Sources		
Existing development	Stormwater	2
Brake pads	Stormwater	3
Ceramics	Wastewater	3
Wood finishers	Wastewater	4
Jewelry manufacturing	Wastewater	5
Mobile cleaners	Stormwater	6
Cooling water systems	Wastewater	8
New development	Stormwater	9
Painting contractors	Both	10
Boatyards/ marinas	Stormwater	12
Landscape maintenance	Stormwater	12
Laboratories and medical facilities	Wastewater	13
Dentists	Wastewater	14
Machine shops	Wastewater	16
Dry cleaners	Wastewater	17
Photoprocessors	Wastewater	18
Food service businesses	Both	23
Printers	Wastewater	26
Construction and new development	Stormwater	28
Vehicle service facilities	Both	45
Residential Sources		
Pet care	Both	4
Laundry graywater	Wastewater	5
Pools and spas	Both	5
Painting activities	Stormwater	7
Indoor pest control	Wastewater	10
Corrosion	Wastewater	11
Root control products	Wastewater	12
Vehicle maintenance	Stormwater	15
Household cleaners	Wastewater	20
Landscape maintenance	Stormwater	24

Little work addresses laundry graywater, pools and spas, painting activities, root control products, and pet care. Laundry graywater appears to be a significant source of several metals in wastewater. Painting activities do not appear to represent a substantial source of metals or other pollutants currently under evaluation. Pools, spas, and root control products are associated primarily with copper. Pet care is likely to be a significant source of pesticides to wastewater.

Public Education

An extensive effort has been dedicated to educating the public about preventing stormwater and wastewater pollution. The messages are fairly uniform from program to program. These messages communicate what the wastewater and stormwater concerns are and what individuals can do about them. While the public is receiving the same key messages, there is no uniform catch–phrase or slogan (e.g., "Reduce, Reuse, Recycle" or "Give a Hoot, Don't Pollute). From a marketing point of view, a consistent message would help stormwater and wastewater pollution prevention programs achieve an even stronger public recognition of the issues.

Audiences targeted by public education campaigns include the general public, ethnic communities, commercial businesses, municipal workers, and school programs. Effective strategies used to approach these sources include the use of the media (i.e., television, radio, newspapers), participation in public events, presentations at workshops and trade shows, videos, course curricula, and advertisements and promotional items.

Emerging areas of development in public education are watershed management to promote pollution prevention and the use of social marketing and behavior change principles to develop wastewater and stormwater public education programs.

Program Effectiveness

While many agencies have indicated a need to evaluate the effectiveness of their wastewater, stormwater, and public education programs, little information is available concerning tools for measuring effectiveness. Some information is available on using water quality measurements, other environmental criteria, financial value, and surveys as indicators of effectiveness. Models have been developed to help predict program effectiveness based on such parameters as water quality data and demographic data. In general, there appears to be a lack of understanding of how to measure program effectiveness. More work developing the proper tools and understanding how to incorporate them into pollution prevention programs is clearly needed.

Conclusions

Based on the results of the literature assessment, recommendations concerning future research and program needs include:

- Developing a method for addressing issues beyond a local government's jurisdiction (e.g., reduction of copper levels in brake pads);
- Developing a research program and mechanism for addressing cross-media pollution prevention issues;
- Conducting a monitoring program to characterize non-stormwater discharges;
- Applying scientific principles to do public education;
- Establishing a wastewater/ stormwater pollution prevention information resource;
- Developing tools to measure program effectiveness;
- Developing a uniform catch phrase for stormwater and wastewater pollution prevention;
- Producing a CD-ROM containing examples of public education materials; and
- Focusing pollution prevention strategies and public education materials on locally important pollutants of concern.

Additional program development is needed for such commercial and residential sources as automotive brake pads, new development, vehicle related activities, pesticide users, mobile cleaners, and laundry graywater.

Acronyms Used in This Report

ACCWP	Alameda Countywide Clean Water Program
AMSA	Association of Metropolitan Sewerage Agencies
APA	Alan Plummer Associates
BAPPG	Bay Area Pollution Prevention Group
BASMAA	Bay Area Stormwater Management Agencies Association
BERC	Sacramento Business Environmental Resource Center
BMPs	Best management practices
BOD	Biochemical oxygen demand
CBP	Chesapeake Bay Program
CCCSD	Central Contra Costa Sanitary District
CCCWP	Contra Costa Clean Water Program
CCSF	City and County of San Francisco

CETA	Cleaning Equipment Trade Association
CIP	Compliance incentive program
CIWMB	California Integrated Waste Management Board
CMP	Code of management practices
CSO	Combined sewer overflow
CVRWQCB	Central Valley Regional Water Quality Control Board
DCDPW	Washington, D.C. Department of Public Works
DNR	Wisconsin Department of Natural Resources
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EBDA	East Bay Dischargers Association
EBMUD	East Bay Municipal Utility District
EOA	Eisenberg, Olivieri and Associates
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
GAO	General Accounting Office
GBNEP	Galveston Bay National Estuary Program
GIS	Geographical information system
GREEN	Global Rivers Envinronmental Education Network
IDNR	Iowa Department of Natural Resources
IEPA	Illinois State EPA
IPA	Isopropyl alcohol
IPM	Integrated pest management
IWRC	Iowa Waste Reduction Center
LWA	Larry Walker Associates
MAHL	Maximum available headworks loading
MDE	Maryland Department of Environment
Mgal/day	Million gallons per day
Mgal/yr	Million gallons per year
MMSD	Milwaukee Metropolitan Sewer District
MOPP	Mobile outreach pollution prevention
MSDS	Material safety data sheet
MSU	Montana State University
MT P2	Montana Pollution Prevention Program
NCBA	National Cattlemen's Beef Association
NCSU	North Carolina State University
NCTCOG	North Central Texas Council of Governments

NIPC	Northeastern Illinois Planning Commission
NJDEPE	New Jersey Department of Environmental Protection and Energy
NPDES	National pollutant discharge elimination permit
NPPR	National Pollution Prevention Roundtable
NSD	Novato Sanitary District
NSMP	Novato source monitoring program
NURP	National urban runoff program
NYCDEP	New York City Department of Environmental Protection
OGS	Oil-grit separators
OTA	Massachusetts Office of Technical Assistance
PARWQCP	Palo Alto Regional Water Quality Control Plant
PC	Particulate carbon
PINC	Printing Industries of Northern California
POC	Pollutants of concern
POTW	Publicly owned treatment works
PSA	Public service announcement
PSWQA	Puget Sound Water Quality Authority
QA/QC	Quality assurance/quality control
RMP	Regional monitoring program
SAIC	Science Applications International Corporation
SBSA	South Bayside System Authority
SCVNPS	Santa Clara Valley Nonpoint Source Pollution Control Program
SCWA	Sonoma County Water Agency
SEWPCP	Southeast Water Pollution Control Plant
SFBAPPG	San Francisco Bay Area Pollution Prevention Group
SFEI	San Francisco Estuary Institute
SFRWQCB	San Francisco Bay Area Regional Water Quality Control Board
SIU	Significant industrial user
SPMDs	Semipermeable polymeric membrane devices
SRCSD	Sacramento Regional County Sanitation District
SVOCs	Semivolatile organic compounds
TBT	Tributyltin
TCDD	Dioxins
TDS	Total dissolved solids
TIEs	Toxicity identification evaluations
TITP	Terminal Island Treatment Plant

TOPs	Toxic organic pollutants
TRE	Toxicity reduction evaluation
TSS	Total suspended solids
UDP	Unsafe disposal practices
USD	Union Sanitary District
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VCSQMP	Ventura Countywide Stormwater Quality Management Program
VOCs	Volatile organic compounds
WCC	Woodward-Clyde Consultants
WEF	Water Environment Federation
WEFTEC	WEF Technical Exposition and Conference
WERF	Water Environment Research Foundation
WET	Water Education for Teachers
WLSSD	Western Lake Superior Sanitary District
WPCP	Water pollution control plant
WQC	Water quality criteria
WQO	Water quality objectives
WQS	Water quality standards
WRAP	Waste Reduction and Assistance Program
WTC	Washington Toxics Coalition
WWTP	Wastewater treatment plant

CHAPTER 1.0

INTRODUCTION

This report presents the results of a national assessment regarding commercial and residential sources of wastewater and stormwater pollution. The Water Environment Research Foundation (WERF) sponsored this project to identify existing activities and future research needs for stormwater and wastewater pollution prevention programs. This assessment focuses on pollution prevention programs for wastewater and stormwater that target commercial and residential sources. Pollution prevention programs targeting hazardous waste and air quality have also been developed but are not the focus of this report. This chapter discusses background information, the purpose of the project, the project methodology, and an overview of stormwater and wastewater pollution prevention projects in the United States.

1.1 Background

Regulations affecting publicly owned treatment works (POTWs) have increased over the years, and water quality standards have become more stringent. To comply with regulations and achieve water quality standards, POTWs have the choice of either implementing new treatment technologies or effectively reducing pollutant discharges through source control efforts. Very often treatment alternatives are not economically feasible, and source control represents the more cost–effective and reasonable option. While industrial wastewater discharges can sometimes be effectively controlled through pretreatment programs, the resulting reductions in pollutant loadings are not necessarily adequate to meet increasingly stringent water quality objectives. Communities are looking to nontraditional sources (i.e., residential and commercial sources) to achieve the necessary reductions. New regulations have also made it necessary for communities to evaluate discharges to their stormwater systems. Similar to wastewater, industrial regulation alone will not adequately reduce the levels of pollutants in stormwater. Control of non–industrial stormwater discharges might also become necessary.

To achieve improved water quality, significant sources of wastewater and stormwater pollutants should be identified, and effective source control strategies should be implemented. Some communities have conducted source identification studies and implemented source control strategies for non-industrial sources of wastewater and stormwater pollutants. However, the body of knowledge regarding types of non-industrial sources and appropriate control strategies remains incomplete.

A need exists to identify the significant non-industrial sources of stormwater and wastewater pollution and to critically assess source control strategies currently in use. This identification and assessment process will aid communities in their efforts to reduce water pollution. Ample evidence points to commercial and residential source control as an important step toward further reducing municipal pollutant loadings. In many communities, non-industrial discharges account for the major portion of loadings of several key pollutants in wastewater. For example, studies by wastewater treatment plants in the South San Francisco Bay Area show that about 80% of copper, a pollutant of great concern in the Bay, comes from non-industrial sources (Palo Alto Regional Water Quality Control Plant [PARWQCP] and Montgomery Watson, 1994; City of Sunnyvale and EOA, 1993; City of San Jose, 1993). Therefore, pollution prevention programs in the San Francisco Bay Area have targeted residential and commercial activities over the last few years to further reduce pollutant loadings. Additional studies conducted in other parts of California have confirmed the significant contribution of non-industrial discharges (Larry Walker Associates [LWA], 1994b; Montgomery Watson, 1994a).

Pollution prevention is the most promising approach to addressing non-industrial discharges that contribute to water quality issues nationwide. However, due to limited resources, future local efforts promise only a patchwork of information about individual facilities.

Pollution prevention efforts cannot be focused effectively without source identification information. A comprehensive non-industrial source identification study is necessary to avoid duplication of effort among local governments and maximize the resources available to implement pollution prevention programs. The analysis will start with a review and assessment of the work that has already been conducted concerning source identification. Once sources are identified, feasible pollution prevention measures (best management practices [BMPs] and other strategies) can be developed and implemented. Typical command-and-control efforts that are used for industrial sources are not easily applied to non-industrial sources. Source control strategies that can be effective for commercial and residential sources include public education, legislative approaches, and technical approaches. Compilation and evaluation of existing materials from a cross-section of communities will aid in the development of effective control strategies to address new sources of pollutants, as well as assist researchers to identify where new studies are necessary.

1.2 Project Purpose

This project report will serve as a resource for communities implementing pollution prevention and stormwater programs. A second objective was to identify future research needs with respect to commercial and residential sources of wastewater and stormwater pollution. This project was initiated to help communities effectively focus and plan their source control efforts by compiling and reviewing existing information, identifying information gaps, and recommending future directions and research needs. This project involved a review of research literature, as well as engineering and economic studies, a nationwide survey of public education and pollution prevention programs, and a comprehensive evaluation of information collected for different pollutant sources. The specific topics addressed include the following:

- Pollutants identified in different regions of the U.S.;
- Residential sources of pollutants;
- Commercial sources of pollutants;
- Source control strategies used to address commercial and residential sources;
- Effectiveness of these strategies based on environmental benefits and cost benefits;
- Factors contributing to regional similarities and differences; and
- Factors contributing to similarities and differences in stormwater and wastewater pollutant sources and source control strategies.

1.3 Project Methodology

To evaluate existing information regarding commercial and residential pollutant sources, a review was conducted in the following areas:

- Residential and commercial monitoring studies;
- Source control strategies used to address commercial and residential sources;
- Public education programs used to create general awareness and to target specific sources;
- Observed effectiveness of strategies which have been used to date to address commercial and residential sources.

To compile this information, literature searches were conducted through published databases and the internet. However, much of the information required is not available through published literature. A focused approach was used to contact leaders in stormwater and pollution prevention programs throughout the country. United States Environmental Protection Agency (US EPA) regional and national coordinators for stormwater and pollution prevention were first contacted and asked to identify the best programs in their regions. Representatives of the recommended programs were then approached for information about their specific projects.

Developing stormwater contacts through US EPA regional stormwater coordinators was an effective method of finding the leaders in stormwater pollution prevention. However, regional pollution prevention coordinators were often more aware of pollution prevention efforts targeting hazardous waste or air pollution rather than wastewater or stormwater. To supplement the gaps with respect to wastewater, additional contacts were made through the Water Environment Federation (WEF) pollution prevention committee, Association of Metropolitan Sewerage Agency (AMSA) 1996 pretreatment workshop participants, and US EPA regional pretreatment program coordinators.

Over 300 people were contacted throughout the U.S. Each contact was interviewed briefly via telephone about the program emphasis (i.e., stormwater or wastewater), pollutants evaluated, and efforts pertaining to commercial or residential sources. Based on the results of the phone contact, a questionnaire requesting more detailed information was sent. The contacts were asked to fill out the questionnaire and return it along with a list of reports or other literature available from their programs. The project team followed up to obtain the literature of interest. Approximately 60 program representatives returned completed questionnaires, which provided the basis for this report. A list of programs and contacts providing information for the source control assessment are listed in Appendix A. A copy of the phone interview and questionnaire are found in Appendix B.

While not every program in the U.S. was assessed, the programs included represent the current status of pollution prevention and stormwater programs targeting residential and commercial sources. Approximately half of the programs reviewed using this approach are located in California. The project team is located in California which may have resulted in a greater response from California programs. Even so, stormwater and wastewater pollution prevention contacts were made in every region of the United States. Regional differences are accounted for through the nationwide contacts that were established.

1.4 Wastewater and Stormwater Pollution Prevention Programs in the United States

As part of this WERF project, representatives of wastewater and stormwater pollution prevention programs around the country were interviewed regarding their programs. In some cases, contacts were difficult to establish and other avenues were explored to obtain a complete picture of nationwide activities. These avenues included literature searches, review of "home pages" on the Internet, and review of case studies (e.g., US EPA, 1994; National Pollution Prevention Roundtable, 1995). In several parts of the country, pollution prevention programs have been developed to target hazardous waste rather than wastewater or stormwater. In some cases, water pollution prevention programs have been developed that primarily target industrial activities. In general, these hazardous waste and industrial programs are not discussed in this report. This section provides an overview of wastewater and stormwater pollution prevention programs targeting commercial and residential sources in the U.S. according to US EPA region. Some national efforts are also highlighted. The U.S. is divided into 10 regions according to regional US EPA office jurisdictions as shown in Figure 1-1.

For each US EPA region, the following elements are discussed:

- Highlights of programs reviewed in this report; and
- Areas of focus (stormwater and/or wastewater).

Regional programs that are highlighted in this report are summarized in Table 1-1. A list of people contacted for the programs discussed in this report is found in Appendix A. In addition to the overview in this section, program activities are discussed in detail in the appropriate sections of the report.

1.4.1 Region 1

Region 1 includes the New England States of Maine, Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island. Programs reviewed in Region 1 include the Massachusetts Office of Technical Assistance, the Massachusetts Water Resource Authority, the New Hampshire Department of Environmental Services, Narragansett Bay Commission, and Save The Bay.

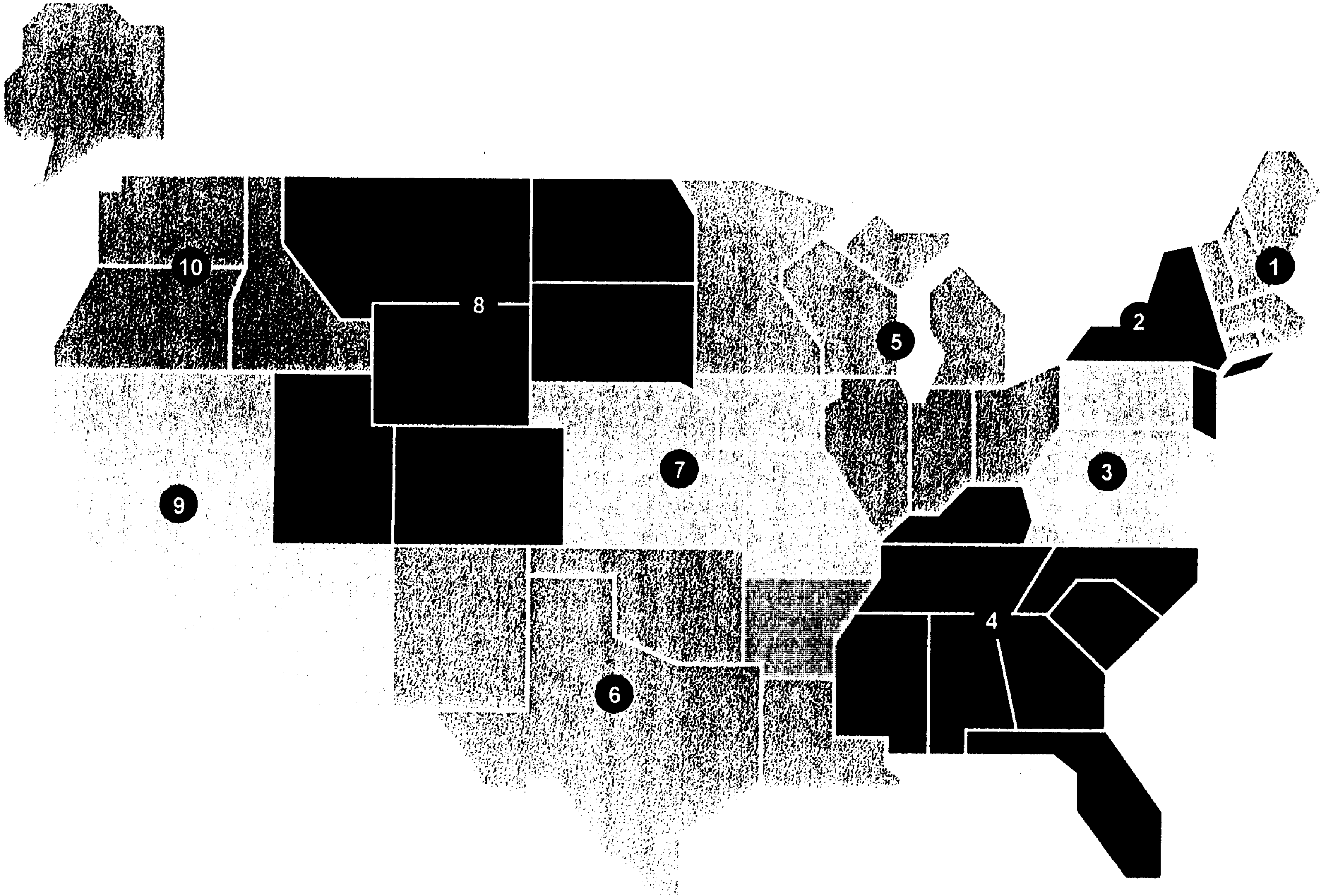

Figure 1-1. US EPA Regions

Table 1-1. Regional Pollutant Evaluation

Region	Source of Information (Agency/Organization)	Program (1)
1	Massachusetts OTA Critical Parameters Project Massachusetts Water Resource Authority Save The Bay Toxic Diet Project Narragansett Bay Commission	P2 P2,SW P2 P2
2	New Jersey Environmental Federation Connecticut Water Management Bureau NY/NJ Harbor Estuary Program	P2 SW SW
3	Chesapeake Bay Program Delaware Department of Natural Resources (DNR) Maryland Department of the Environment City of Alexandria	SW SW SW P2, SW
4	Dade County, Florida Lee County, Broward County - Florida North Carolina	P2 P2, SW P2, SW
5	Wisconsin DNR Rouge Program Office Northeastern Illinois Planning Commission Western Lake Superior Sanitary District, Minnesota Pollution Control Agency	SW SW SW P2
6	City of Greenville, Oklahoma City City of Albuquerque North Central Texas Council of Governments Texas	P2 P2 SW P2
7	Region 7 Nonpoint Source Programs	SW
8	Colorado Stormwater programs City of Boulder	SW P2
9	San Francisco Bay Area Southern California Central Valley Arizona	P2, SW P2, SW P2, SW P2, SW
10	Seattle, King County	P2
Nationwide	WEF Pollution Prevention Committee	P2
	Silver Coalition	P2

(1) P2 = Wastewater Pollution Prevention
SW = Stormwater Pollution Prevention

The Massachusetts Office of Technical Assistance (OTA) has conducted several pollution prevention programs working with POTWs (US EPA, 1994; Offen, 1996). The Critical Parameters project is a US EPA-funded project that developed programs for small businesses (Very Small Quantity Generators) and the general public. The program targets copper, cadmium, nickel, and zinc. Outreach to the general public included a half-hour video explaining the effects of water pollution and a guidebook concerning household pollution prevention opportunities. In addition, a school curriculum was developed for elementary age students.

The Massachusetts Water Resource Authority has a substantial pollution prevention effort targeting copper, lead, mercury, petroleum hydrocarbons, and pesticides (McManus, 1996). Activities so far have targeted household hazardous waste generation. Commercial efforts are starting with the sampling of car washes. In addition, this agency has conducted extensive residential and stormwater monitoring.

The New Hampshire Department of Environmental Services provided information regarding their stormwater program for new development and timber harvesting (Spaulding, 1996).

Save The Bay is an organization in Region 1 that seeks to "ensure that the environmental quality of Narragansett Bay and its watershed is restored and protected from the harmful effects of human activity" (Save The Bay, 1996). To help small-flow POTWs meet their NPDES permit limits, Save The Bay initiated the Toxic Diet Project as a model project in Northbridge, Massachusetts (Wilder, 1994). It involves a collaboration with residents, businesses, and local agencies to identify sources of metals from residential sources, commercial sources, and water conveyance piping (i.e., corrosion) and to implement source reduction. The Narragansett Bay Commission also provided information on source control activities in this region.

1.4.2 Region 2

Region 2 includes New York, New Jersey, Puerto Rico and the Virgin Islands. Information was provided by the Region 2 US EPA Office (Bosques, 1996) and the New York-New Jersey Harbor Estuary Program (Ausubel, 1996). In addition, a case study for Erie County, NY, was reviewed (NPPR, 1995).

Pollution prevention project information was provided by US EPA Regional Pollution Prevention Program (Sapadin, 1996). Grant projects targeting low income and minority communities were described. One grantee, the New Jersey Environmental Federation provided information on its projects (Goldsmith, 1996). These projects target residential sources of metals (lead and mercury in particular) and pesticides. Approaches include surveys, development of outreach materials, and work with local government. Information on stormwater projects targeting certain commercial activities was provided by the Region 2 US EPA office, as well.

A comprehensive plan has been developed to establish and maintain a healthy and productive ecosystem in the New York-New Jersey Estuary and New York Bight (NY/NJ Harbor Estuary Program, 1996). The plan includes actions to address toxic pollutants, management of dredged material, stormwater run-off, pathogens, floatable debris, and nutrients. The emphasis for toxic pollutants is on metals and pentachlorobenzenes (PCBs). Planned actions revolve around more stringent permit limits, sediment clean-up, additional source identification, and additional monitoring. Intensive public outreach is planned as this project moves into implementation.

The Erie County Office of Pollution Prevention provides technical assistance to small businesses and is currently working with local POTWs to promote pollution prevention (NPPR, 1995).

1.4.3 Region 3

Region 3 includes the Mid-Atlantic States of Pennsylvania, Delaware, Maryland, Virginia, West Virginia, and the District of Columbia. Stormwater programs are well developed in this region, with much of the activity centering around efforts to protect the Chesapeake Bay. The Chesapeake Bay Program, construction programs in Maryland and Delaware, and wastewater and stormwater pollution prevention activities in Virginia were reviewed.

Information regarding the Chesapeake Bay Program has been collected through the literature and the Chesapeake Bay Program's home page on the Internet. The Chesapeake Bay Program (CBP) began in 1983 through the cooperative efforts of the States of Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission; US EPA; and advisory groups. (The Chesapeake Bay Program, 1996; Hudson, 1995) The CBP was initiated in order to restore the estuary and address three issues: nutrient over-enrichment, dwindling bay grasses, and toxic pollution. Specific actions initiated by the CBP include a phosphate detergent ban, introduction of agricultural BMPs, biological nutrient removal, a citizen's monitoring program, and an intensive public education campaign emphasizing the role of individual residents in the Bay's restoration. Substantial progress had been seen by 1993, including increases in acreage of underwater bay grasses, record setting numbers of young rockfish, and reductions of point source pollution. Nutrient reduction efforts have been expanded to include setting reduction targets for the Bay's tributaries in addition to the Bay itself.

Contractor certification programs in Delaware and Maryland are described in this report (Shaver, 1993; Non-Point Source News Notes, 1995a).

Pollution prevention activities in Virginia were summarized as part of a commercial business evaluation (MEB, 1994). Businesses targeted include printers, wood finishers, dry cleaners, and marine maintenance facilities. Stormwater and pollution prevention activities in Alexandria, VA, are also discussed herein.

1.4.4 Region 4

Region 4 includes the southern States of Kentucky, Tennessee, North Carolina, South Carolina, Florida, Georgia, Alabama, and Mississippi. Pollution prevention and stormwater programs in North Carolina and Florida were reviewed. Some information was also provided by programs in South Carolina and Tennessee.

Pollution prevention programs in Florida include State programs and those implemented in Broward, Dade, and Lee Counties (Opris, 1996; Cuniff, 1996; Nottingham, 1996). Targeted activities include hotels/motels, marinas, and salvage yards, in addition to some of the more common businesses (i.e., vehicle service, printers, photoprocessors). Broward County has developed pollution prevention and BMPs through a collaborative effort with marine facilities and automotive salvage yards (NPPR, 1995). Dade County has an extensive pollution prevention program targeting several business categories, as well as residents and visitors. Source control strategies for business include training, workshops, BMP booklets, and on-site audits. Businesses targeted include printers, dentists, radiator shops, and photoprocessors. Residential outreach has been conducted through schools, television, radio, newsletters, billboards, and through outdoor cleanup, and tree planting activities.

Pollution prevention and stormwater programs in North Carolina also appear to be comprehensive. The North Carolina State University Water Quality Group acts as a resource center and provides technical assistance with respect to stormwater issues. They have developed a comprehensive list of BMPs for activities impacting stormwater (NCSU, 1996). The North Carolina Office of Waste Reduction is a resource and technical assistance center for pollution prevention activities (Hunt, 1996). This office has an extensive library and database of articles and information relating to pollution prevention and conducts on-site audits and workshops and training for business.

1.4.5 Region 5

Region 5 includes the Great Lakes States of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The Region 5 US EPA office identified contacts and provided background information on key programs. Stormwater program information in Region 5 was provided by the Wisconsin Department of Natural Resources (DNR), the Rouge Program Office, and the Northeastern Illinois Planning Commission. Pollution prevention activities in Minnesota and Wisconsin were also reviewed.

Wisconsin DNR has conducted extensive monitoring and source identification for stormwater pollutants (Bannerman, 1996). In addition, they have developed outreach materials pertaining to pesticide use and construction activities.

In Michigan, the Rouge River Stormwater Program has developed outreach on several fronts and has initiated a Rouge Friendly Business Program and a Clean Neighborhood Program to recognize efforts to control commercial and residential sources of stormwater pollution (Reaume, 1996).

The Northeastern Illinois Planning Commission has developed stormwater guidance materials including guidance information and an instructional video pertaining to sediment and erosion control.

With respect to wastewater pollution prevention, the Milwaukee Metropolitan Sewer District in Wisconsin and the Western Lake Superior Sanitary District in Minnesota have developed interesting programs with respect to mercury sources, including dentists, hospitals and laboratories (MMSD, 1991; Tuominen, 1996).

1.4.6 Region 6

Region 6 includes the Gulf Coast States of Louisiana, Oklahoma, Texas, Arkansas, and New Mexico. Pollution prevention programs were reviewed in Oklahoma, Texas, and New Mexico. Stormwater programs were reviewed in Texas.

Diazinon has been associated with whole effluent toxicity failures for several POTWs in Region 6 (APA, 1995; Erwin, 1996). Programs in Oklahoma and Texas targeting residential use of diazinon and other pesticides are discussed herein. The City of Albuquerque, New Mexico has an extensive pollution prevention program for small businesses, particularly those identified as sources of silver

(Hogrefe, 1996). Workshops, guidance manuals, and a recognition program are used to encourage businesses to meet the silver discharge limits.

With respect to stormwater, the North Central Texas Council of Governments has developed a regional stormwater program addressing pesticides, nutrients, sediments, metals and fecal coliform (NCTCOG, 1996). Program implementation includes an extensive public awareness effort, residential and commercial runoff monitoring, source identification, and industrial BMP development. Monitoring studies conducted in Galveston Bay, Texas, are discussed elsewhere in this report (Galveston Bay National Estuary Program, 1992).

1.4.7 Region 7

Region 7 includes the Midwestern States of Kansas, Iowa, Missouri, and Nebraska. Contacts in this region indicated that stormwater programs are in the initial stages of development with monitoring, brochure distribution, and storm drain stenciling being the extent of the activities undertaken to date (Coonley, 1996; Wurtz, 1996). In addition, POTWs have felt little pressure up to this point to implement pollution prevention because pollutant levels in their effluent are not of concern in most cases.

Pollution prevention activities in this region seem to focus on small businesses through assistance centers that have been developed at the University of Northern Iowa and the Iowa Department of Natural Resources. While these programs were largely developed in response to air quality and hazardous waste issues, programs and information have been developed that are useful for wastewater, as well. The Iowa Waste Reduction Center at the University of Northern Iowa has developed excellent guidance manuals for printers and vehicle service facilities (IWRC, 1995). The Iowa Department of Natural Resources has a non-regulatory assistance program staffed by retired industry professionals called the Waste Reduction and Assistance Program (WRAP) (Wnuk, 1996).

1.4.8 Region 8

Region 8 includes the Rocky Mountain States of Colorado, Montana, North Dakota, South Dakota, Wyoming, and Utah. Pollution prevention and stormwater programs in Colorado and Montana provided information for this study. Some program aspects in Fort Collins and Boulder, Colorado, and the Montana Pollution Prevention Program are highlighted in the paragraphs which follow.

The City of Fort Collins, Colorado is developing a stormwater program using a watershed approach (McBride, 1996). As part of this approach, pollution prevention strategies have been implemented including household hazardous waste collection, use of integrated pest management for public lands, and spill prevention plans. Public outreach efforts include a children's water festival, a master naturalist program, storm drain stenciling, and a citizen monitoring project.

The City of Boulder's pretreatment program has investigated commercial sources, including food service facilities, printers, photoprocessors, medical facilities, vehicle service facilities, and dry cleaners (Erickson, 1996). Outreach to these businesses includes a semi-annual pretreatment newsletter and small business pollution prevention seminars.

The Montana Pollution Prevention Program (called MT P2) at Montana State University has developed a variety of outreach materials and conducted training for several small business categories including dry cleaners, vehicle service, printers, hospitality industry, wood finishing, and construction (Montana State University, 1996). In addition, this program provides pollution prevention education to Native American communities.

1.4.9 Region 9

Region 9 includes the Western States of California, Arizona, Nevada, and Hawaii. Numerous programs in Arizona and California provided information for this project. Program elements are discussed in detail throughout the rest of the report. Some brief information about programs in Phoenix, the San Francisco Bay Area, the Central Valley, and Southern California is presented in the following paragraphs.

In Arizona, the Phoenix Pollution Prevention Program and stormwater program provided extensive information (Sundstrom, 1996; Menke, 1996). Both programs have comprehensive, creative public outreach materials. As one example, the Pollution Prevention Program has created an interactive, "Jeopardy" style game for businesses (Pollution Prevention Pays) and the general public (Be A Pollution Solution). These games are used at trade shows and public events. Other aspects of the Phoenix programs are described throughout the report.

The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) requires the use of pollution prevention to address pollutants through its NPDES permits. Several agencies have developed innovative programs in response to this requirement. In addition, POTWs work together on projects of regional interest through the San Francisco Bay Area Pollution Prevention Group

(SFBAPPG). A few of the group's accomplishments are (1) regional outreach materials targeting copper sulfate root control products and vehicle service facilities; (2) a regional video explaining wastewater and stormwater issues; (3) a source identification study for copper in wastewater; and (4) a source identification study for toxic organic pollutants in wastewater (Louie, 1996). These and other SFBAPPG projects are discussed throughout the report.

A wide range of outreach to businesses, including vehicle service facilities, printers, medical facilities, cooling towers, and dentists, has been implemented by public agencies in the Bay Area. Some of the programs from this area that are highlighted in this report include the City and County of San Francisco (CCSF), the Palo Alto Regional Water Quality Control Plant (PARWQCP), East Bay Municipal Utility District (EBMUD), Union Sanitary District (USD), City of Sunnyvale, and Central Contra Costa Sanitary District (CCCSD).

Stormwater activities in the Bay Area are conducted in cooperation with wastewater pollution prevention activities in many cases. Such activities include programs developed for pesticide use, mobile cleaners, and construction activities. Regional outreach programs are developed through the Bay Area Stormwater Management Agencies Association (BASMAA). Stormwater programs in the Bay Area that are highlighted in this report include the Alameda Countywide Clean Water Program (ACCWP) and the Santa Clara Valley Nonpoint Source Pollution Control Program (SCVNSPCP). Some examples include pesticide source identification efforts and outreach targeting construction activities and new development.

In the Central Valley of California, projects addressing construction sources of pollutants and sources of organophosphate pesticides in stormwater are being conducted through the Sacramento Stormwater Program and the Central Valley Regional Water Quality Control Board (CVRWQCB). In addition, pollution prevention outreach for commercial facilities, such as dry cleaners, vehicle service facilities, printers, and wood finishers, has been developed by the Sacramento Regional County Sanitation District (SRCSD) and the Business Environmental Resource Center (BERC) (Harader, 1996).

In Southern California, wastewater pollution prevention efforts focus primarily on industry. Stormwater programs in Ventura County and Riverside County have extensive outreach targeting both commercial and residential sources. The Ventura Countywide Stormwater Management Program (VCSQMP) has developed outreach and recognition programs for vehicle service facilities and food service businesses (VCSQMP, 1995b). Riverside County has developed guidance for construction and new development and general awareness outreach for the general public (Ristow, 1996; Summers, 1996).

1.4.10 Region 10

Region 10 includes the Pacific Northwest States of Washington, Oregon, Idaho, and Alaska. The preponderance of activity reviewed for this report is located in the Seattle-King County area of Washington. Some stormwater program information was also provided by the Department of Public Works in Anchorage, Alaska.

Seattle METRO and King County Hazardous Waste Management Program work together to implement business inspection and assistance programs, pesticide public outreach programs, general awareness public outreach, and business recognition programs (Hildebrand, 1996). The Seattle Drainage and Wastewater Utility conducts public outreach and school programs targeting stormwater issues (Chandler, 1996). The City of Bellevue, Washington, developed business outreach materials discussed in this report (Woodward-Clyde, 1990). Washington programs targeting pesticides, dentists, vehicle service facilities, and general public outreach are discussed in more detail throughout this report .

The municipality of Anchorage provided a literature search and analysis of stormwater BMPs conducted in support of their stormwater program (Montgomery-Watson, 1994b; Montgomery-Watson, 1996a). This document provides a comprehensive list of stormwater BMPs divided into the following categories: source reduction practices; erosion, sedimentation, and drainage management practices; vegetative management practices; retention/detention management practices; filtration and infiltration management practices; and material and disposal management practices.

1.4.11 National Efforts

Some efforts have been initiated at a national level to address sources that are of concern to communities nationwide. Two such groups are the Water Environment Federation Pollution Prevention Committee and the Silver Coalition.

The WEF Pollution Prevention Committee is a group of wastewater and stormwater professionals from around the U.S. who work together on pollution prevention issues (Schweinfurth, 1996). They have coordinated national workshops on commercial sources, including photoprocessors and vehicle service facilities. In addition, they have written and produced guidance documents for controlling vehicle service facility discharges, silver discharges, and dry cleaners discharges to wastewater. Future activities include publishing guidance manuals for dental offices and industrial laundries and developing a source control training program for small municipalities.

The Silver Coalition, in cooperation with the Association of Metropolitan Sewerage Agencies (AMSA), has developed a code of management practice (CMP) for silver dischargers (Silver Coalition, 1995). It contains recommendations on technology, equipment, and management practices for controlling silver discharges that process photographic materials. This CMP will be used to develop a consensus among the regulated and regulatory communities for controlling silver discharges in a cost-effective and environmentally sound manner. The Silver Coalition worked with other agencies, including US EPA and WEF, to develop this manual. In addition, pilot efforts have been conducted in municipalities from different parts of the country. The CMP has been implemented in Hampton Roads, VA, Albuquerque, NM, and Colorado Springs, CO.

CHAPTER 2.0

MONITORING AND SOURCE IDENTIFICATION

Numerous monitoring programs have been conducted by Federal, State, county, city, and environmental agencies to determine the pollutants in wastewater and stormwater that ultimately impact receiving waters and to identify the sources of these pollutants. These investigations indicate that commercial and residential sources contribute significant amounts of pollutants to both wastewater and stormwater flows. As a result, several programs have monitored specific commercial and residential activities. This chapter includes information on monitoring of wastewater and stormwater discharges from commercial and residential land use areas in various regions of the U.S. This chapter is not a comprehensive evaluation of the available monitoring information, but a summary of selected studies that are representative of the types of investigations that have been conducted. Information presented is organized by program type (i.e., receiving water, stormwater, or wastewater) and then by region.

A summary of the studies reviewed in this chapter, including location, program type, affected water body, pollutants of concern, and the sampling site or commercial/residential source(s) identified, are presented in Table 2-1. Information on other monitoring and source identification projects identified during this study but not selected for review are presented in Table C-1 (Appendix C). According to Tables 2-1 & C-1, wastewater and/or stormwater monitoring of commercial and residential land use areas has been conducted in each US EPA region, and many of these investigations have targeted specific commercial and residential activities. The following sections discuss selected monitoring and source identification studies.

Table 2-1. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
1 Rhode Island, Massachusetts	WW[1]	Narragansett Bay	Cu Pb Zn	pipe corrosion not identified not identified
2 New York/New Jersey (NY/NJ)	WW, SW[2]	NY/NJ Harbor	Metals PCBs Cyanide	tributaries & municipal inputs tributaries municipal discharges
3 Chesapeake Bay	SW, receiving water, sediments	Chesapeake Bay	PAHs, As, Ni Cyanide, Cd, Zn Cr, Pb, pentachlorophenol Bis-(2-ethylhexyl)phthalate Cd, Cr, Cu, Zn nutrients	incomplete fossil fuel combustion (home heating units) automobile related activities exterior paints and stains plasticizer (garden hoses, food packaging, etc.) corrosion of metal alloys WW, agricultural land and developed land; sediment runoff from farms, construction sites & other lands
3 Chesapeake Bay	WW, SW, receiving water, sediments	Elizabeth River	PAHs TBT	dumping of oily wastes & creosote, combustion of fosssil fuel antifouling paint applied to watercraft
3 Maryland	SW	Maryland Piedmont	Hydrocarbons, PAHs, metals	service stations, convenience commercial, commuter parking lots

Table 2-1, cont. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
5 Wisconsin	SW	Milwaukee River and Sheboygan River watersheds	Pb, pesticides, bacteria	medium density residential areas
5 Wisconsin	SW, receiving water, sediment, whole fish & crayfish tissue	Madison surface waters	Zn Phosphorus Total solids, TSS, phosphorus, Cd, Cu, Cr, Pb, Zn As, Cd, Cr, Cu, Pb, Ni, Se, Ag, Zn Methoxychlor semi volatile organic compounds	roof runoff lawns and driveways street runoff detected at commercial & university sites detected at university site detected at commercial, high density residential, highway, and shopping center sites
5 Wisconsin, Michigan, Minnesota	SW	Lake Superior	Nutrients, metals, PAHs	runoff (non-specific)
5 Illinois	SW, receiving water	agricultural watershed surface waters	pesticides	runoff
6 Texas	SW	Galveston Bay	TSS, phos., nitrogen, BOD, oil & grease, bacteria, Cu, pesticides	most significant source areas were high density urban residential and barren areas
7 Dallas/Fort Worth, Texas	SW	not specified	Cd, Cr, Cu, Pb, Zn, Chlordane, Diazinon, bacteria, TSS	non-specific
7 Austin, Texas	SW	not specified	nitrate, Cu, ortho-phosphate, bacteria, sediment	not detected in first flush (first inch of stormwater runoff)

Table 2-1, cont. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
7 Iowa	SW,WW	Iowa's surface waters	pesticides, nutrients, bacteria, sediment ammonia, metals, nutrients, oil & grease, pesticides, BOD sediment, nutrients, bacteria	residential area runoff (SW, lawn watering, motor vehicle washing, fire hydrant flushing) commercial area runoff (SW, commercial facility drains, non-stormwater connections, CSOs) agricultural activites
9 San Francisco Bay Area Pollution Prevention Group	WW	San Francisco Bay and other California Waters	copper Toxic Organic Constituents	radiator repair, auto repair, car washing, cooling towers, dry cleaners, laboratories, laundries, hospitals, photoprocessing, printers, univ./schools, machine shops, metal fabrication, incinerator scrubbers non-specific
9 San Francisco Bay Area	SW, WW, receiving water, sediment	San Francisco Bay	Zn, Se Cu, Hg, Ni, DDE PAHs	runoff (non-specific) WW outfalls, atmospheric deposition, mobilization of sediments (non-specific) automobile exhaust (PAHs in sediment)
9 Santa Clara Valley Alameda County	SW	South & Central San Francisco Bay	Metals, TSS, TDS, hardness, TOC, oil and grease, nutrients, bacteria, toxic organic constituents	urbanized watersheds
9 City and County of San Francisco	WW	Central San Francisco Bay	Cu, Pb, Hg, Ni, Ag, Zn, cyanide Cyanide Toxic Organic Constituents	household use of motor oil and house paints printers, photoprocessors, vehicle service/repair shops, hospitals, laboratories, restaurants non-specific

Table 2-1, cont. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
9 Palo Alto (RWQCP)	WW	South San Francisco Bay	Diazinon Tributyltin	pesticide applications cooling water systems discharge
9 Novato Sanitary District	WW	San Pablo Bay	Cu Cu, Pb, Ni, Ag Ag, Zn	tap water sources (i.e., corrosión) commercial sources (non-specific) contribute more than residential or WWTP influent unmeasured non-residential sources
9 City of San Jose	WW	South San Francisco Bay	Zn Cu, Ni Ag	greatest contribution from residential & water supply sources (non-specific) corrosion, transportation (airport/terminal), machine shops, hospitals, misc. equip. rental, sheet metal work, lithographics, commercial printing, laundries, dry cleaners, car washes greatest contributions from commercial and residential sources (non-specific)
9 Union Sanitary Dist. (cities of Fremont, Newark, Union City, CA)	WW	Central San Francisco Bay	Cu, Ni	automotive machine shops, printers
9 Central Contra Costa Sanitary District (CCCSD)	WW	Suisun Bay	Chlorpyrifos, Diazinon metals	residential, self-service pet washers, pest control operators, kennels (flea shampoos) residential= laundry grey water, corrosion, root control, household products, vehicle service

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Table 2-1, cont. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
9 South Bayside System Authority (cities of San Carlos, Belmot, Redwood City & West Bay Sanitary District, CA)	WW	Central San Francisco Bay	Cd	auto repair, laundries, indoor household products, greywater
			Cr	laundries, indoor household products, greywater
			Cu	auto repair, photoprocessors, printers, dentists, labs, painting, laundries, cooling towers, indoor & outdoor household products, greywater, copper sulfate root killer, human body wastes
			Hg	hospitals, labs, painting, indoor & outdoor household products, human body wastes
			Pb	auto repair, photoprocessors, laundies, greywater, indoor & outdoor household products
			Mo	printers, painting, outdoor household products
			Ni	auto repair, labs, indoor household products, greywater, human body wastes
			Ag	auto repair, photoprocessors, printers, hospitals, dental offices
			Zn	auto repair, photoprocessors, printers, dental offices, painting, laundries, cooling towers, greywater, indoor & outdoor household products, human body wastes
9 City of Hayward	WW	Central San Francisco Bay	Cu, Diazinon	residential areas (non-specific)
			Pb, PAHs	not identified
9 Sunnyvale	WW	South San Francisco Bay	Cu	corrosion
			Ni	residential and commercial sources (non-specific)

Table 2-1, cont. Pollutants Evaluated and Sources Identified in Regional Water Quality Monitoring Studies

Region & Location or Agency	Type of Monitoring	Affected Water Body	Pollutants Evaluated	Location Sampled or Commercial/Residential Source(s) Identified
9 Ventura County, CA	SW	local rivers and sloughs	not specified	residential, commercial, industrial, agricultural illicit discharges - gas stations, auto service, commercial laundries, carpet cleaners, painters, pool cleaning, salvage yards, recycling facilities, restaurants, machine shops, outdoor storage
9 Orange County Sanitation District	WW		metals, organics, nutrients, oil and grease, TSS	residential sources (non-specific)
9 City of Los Angeles, CA	WW	Los Angeles Harbor	Cu, Zn	radiator & auto shops, dental offices
9 City & County of Sacramento, CA	SW	Sacramento and American Rivers	Cd, Cu, Hg, Zn Diazinon, Chlorpyrifos	acid mine drainage professional landscape maintenance, structural pest control, agricultural uses
9 City of Phoenix, AZ	WW	Phoenix area surface waters	As Hg	natural, commercial and residential greatest sources (non-specific) dentists (most significant source), also sampled printers, photoprocessors, hospitals, labs, auto repair shops, auto service stations, funeral homes, lithographics, glass cutters, ceramics, laundries
10 Washington	SW	Puget Sound	pesticides	drainages (non-specific)
10 Seattle, Washington	WW	not specified	Antimony, Ag, Zn, phthalate, chloroform, PCE, benzene Arsenic	nonindustrial sources (non–specific) dishwashing & powdered laundry detergents, bleach

[1] various sources, see Chapter 2.0 [2]WW = wastewater [3]SW = stormwater

2.1 Receiving Water Monitoring

Several receiving water monitoring programs have been conducted, and many have led to source identification investigations. Programs selected for discussion in this section include NY/NJ Harbor Estuary, Chesapeake Bay, San Francisco Bay, and Santa Monica Bay. Other receiving water investigations identified by the project team but not discussed in this report, include Narragansett Bay (Rhode Island and Massachusetts), Galveston Bay (Texas), Chesapeake Bay tributaries, and Kansas surface waters.

2.1.1 NY/NJ Harbor Estuary (Region 2)

An assessment of the impact of chemicals in the NY/NJ Harbor Estuary system was performed to guide development of future monitoring programs in the estuary (Squibb, O'Connor, and Kneip, 1991). The assessment was performed by collecting water, biota, and sediment samples. Chemicals of concern were determined for the estuary by comparing ambient concentrations observed in water and biota samples with Federal and State marine water quality criteria (WQC). The following chemicals are considered to be of concern for the NY/NJ Estuary based upon water monitoring results:

- Metals: arsenic, beryllium, cadmium, copper, lead, mercury, nickel, silver, zinc

- Pesticides: aldrin, alpha-BHC, gamma-BHC, DDD, DDE, DDT, dieldrin, endosulphan, heptachlor

- Organics: benzene, bis(2-ethylhexyl)phthalate, carbon tetrachloride, chlorobenzene, 1,4-dichlorobenzene, ethylbenzene, methylene chloride, napthalene, n-nitrosodi-n-propylamine, 1,1,2,2-tetrachloroethane, tetrachloroethylene, 1,1,2-trichloroethane, hexachlorobutadiene, PCBs, trichlorethylene

Other pollutants were deemed to be of concern based on fish tissue analysis. These pollutants include PCBs, TCDD, mercury, arsenic, DDT, DDD, DDE, chlordane, dieldrin, heptachlor, heptachlor epoxide, hexachlorobenzene, gamma-BHC, PAHs and tetrachlorodibenzofurans.

Another study, conducted as part of the NY/NJ Harbor Estuary Program, involved chemical analysis and toxicity testing of water column samples collected throughout the estuary (Science Applications International Corp., 1993). The purpose of the study was to assess both small-scale and broad-scale variability in toxicity. Water samples were collected in nonpoint source areas to determine general water quality of the estuary. Two different types of toxicity tests were performed, including the sexual reproduction test with the marine red alga, *Champia parvula*, and the fertilization test with the sea urchin, *Arbacia punctulata*. These methods were selected for several reasons. For example, discrete samples can be tested utilizing these methods, which provides a more detailed characterization of the variability of toxicity. Additionally, the two test species selected are sensitive to heavy metals (*Champia* is especially sensitive to copper), which can cause toxicity in the estuary. Both species were tested on over 130 water column samples from three sampling events (one small-scale event including 4 stations and 2 broad-scale events encompassing the entire Estuary). Water column samples were collected in conjunction with toxicity samples and analyzed for total silver, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, and zinc, as well as total organic carbon (TOC) and total ammonia. The chemical analyses were performed so that chemical concentrations and toxicity could be correlated.

Results demonstrated that many of the ambient samples were toxic to the test species. Toxicity to either *Arbacia* or *Champia* was observed at each station during at least one of the sampling events. However, patterns in toxicity could not be attributed to heavy metals, in particular copper, as thought at the outset of the study. It was concluded that future work should be conducted, including toxicity identification evaluations (TIEs), which would help determine the pollutants present and possibly relate toxicity to potential point sources.

Sediment samples were also analyzed and were found to contain high concentrations of metals (organic chemical concentrations have not been as closely monitored). Chemical concentrations detected in sediment were used to determine potential sources (i.e., areas with high concentrations of metals in sediments were often surrounded by industry or near WWTPs).

An additional study, conducted as part of the US EPA National Estuary Program, determined pollutant loadings for NY/NJ Harbor Estuary. The objectives of this study were to determine the relative importance of each source of pollutants in the harbor, to provide information for a wasteload allocation analysis, and to determine future monitoring objectives (HydroQual, Inc., 1991). The study determined loadings for conventional parameters, nutrients, metals, PCBs, and cyanide from 6 different source classes. Sources included municipal discharges, industrial discharges, runoff loadings, tributary inputs, landfill leachate, and atmospheric deposition. Results demonstrated that metal loadings were primarily from tributaries and municipal inputs. Inputs from combined sewer overflows (CSOs) and atmospheric deposition, however, were also important sources of lead. Tributaries contributed significant amounts of PCBs (50% of the total load), and municipal discharges were responsible for the greatest cyanide inputs (89% of the total load). It is important to note that loadings for some parameters were estimated if actual assessment data were lacking.

2.1.2 Chesapeake Bay (Region 3)

Extensive monitoring studies have been performed in the Chesapeake Bay Area. In 1987, the Chesapeake Bay Agreement was finalized requiring development of a basinwide strategy to reduce toxic loadings to the Bay. As a result of this agreement, the Chesapeake Bay Basinwide Toxics Reduction Strategy was created. The strategy outlined efforts to define the nature, extent, and magnitude of Chesapeake Bay toxics problems and to initiate specific toxics reduction and prevention actions (Chesapeake Executive Council, 1989).

The most recent information is presented in the Chesapeake Bay Basinwide Toxics Reduction Strategy Re-evaluation Report (Chesapeake Bay Program, 1994). Objectives during the re-evaluation included identification of pollutants of concern, estimation of loadings to the Bay, pollutant source identification, source control and pollution prevention. A list of pollutants of concern was compiled for the report which included atrizine, benzo[a]anthracene, benzo[a]pyrene, cadmium, chlordane, chrysene, chromium, copper, fluoranthene, lead, mercury, naphthalene, PCBs, and tributyltin (TBT). A secondary list of toxics included alachlor, aldrin, arsenic, dieldrin, fenvalerate, metolachlor, permethrin, toxaphene, and zinc. Pollutants were included in the primary list if the pollutant had been measured in one of the environmental media in the past. Inclusion was not based upon evidence of potential or existing environmental impact. The list represents those pollutants that will be ranked and identified for future revisions of Bay toxics of concern. The secondary list includes those chemicals that might be considered for inclusion in a future list of toxics of concern.

Monitoring information presented in the re-evaluation report combines all past investigations and discusses results of pollutants detected in microlayer, water column, and sediment samples. Among the metals detected in microlayer samples are aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, selenium, and zinc. Specific values were not presented in the report, but it was stated that microlayer concentrations were generally higher than bulkwater concentrations. Also detected in microlayer samples were TBT and PAHs in the concentration range from 0.005 to 1,171 ng/L and <0.05 to 20 ng/L, respectively. Pesticides and organic compounds were largely undetected, except for dieldrin (1 to 18 μg/L).

Water column concentrations were determined for metals, pesticides and organic compounds and are presented in Table 2-2 for the pollutants of concern. The magnitude of the metals data is an indication that significant widespread concentrations exceeding Federal or State water quality criteria (WQC) are not occurring in the mainstream Bay. However, questions have been raised concerning the quality of available metals data, e.g., dissolved concentrations were not determined; analytical methods might not have been appropriate for ambient conditions.

Table 2-2. Water Column Concentration Ranges of Pollutants of Concern in Chesapeake Bay[1]

Parameter	Concentration Range in Water Column (μg/L)[2]
Atrazine	<1.3 - 2,937
Benzo[a]anthracene	<1.1 - 27.2 ng/L
Benzo[a]pyrene	<2.0 - 137.2 ng/L
Cadmium	<0.2 - 4.7
Alpha-Chlordane	<0.1 - 17.2
Gamma-Chlordane	<0.1 - 9.5
Chrysene	NA
Chromium	<1.0 - 150
Copper	<1 - 68
Fluoranthene	<0.3 - 196.8 ng/L
Lead	<1 - 106
Mercury	<0.2 - 0.7
Naphthalene	<0.2 - 39.5 ng/L
PCBs	95% of the available PCB data were below detection limits
Tributyltin	<1 - 1,801 ng/L

[1] SOURCE: Chesapeake Bay Program, 1994
[2] unless noted otherwise
NA = not available

Pesticides were detected most frequently in the spring and summer months (months of heaviest use), and the highest concentrations detected in surface waters were associated with storms. The following pesticides have been detected in the Bay: 2,4-D, alachlor, aldrin, alpha-chlordane, atrazine, cyanazine, DDT, diazinon, dicamba, dieldrin, fenvalerate, gamma-chlordane, hexazinone, malathion, metolachlor, oxychlordane, picloram, prometone, simazine, and terbacil. However, over 60 pesticides included in the analysis were not detected.

Organic compounds in water column samples were not frequently detected. This might be attributable to sampling and analytical problems and the fact that most organics are readily absorbed to sediments and biota. High concentrations of TBT, however, were detected in several Bay habitats.

The Chesapeake Regional Information Service developed a factsheet for the Elizabeth River and Chesapeake Bay (Alliance of the Chesapeake Bay, 1994), which outlines the pollution problems and solutions for this area. According to the information provided, the Elizabeth River is one of the most polluted bodies of water in the entire Chesapeake Bay watershed. Loadings of lead, copper, and mercury were reported at levels 2 to 10 times higher that those in mid-Bay or the Potomac River.

Elevated concentrations of PAHs were detected in the Elizabeth River and were found to adversely impact fish species (e.g., skin lesions, cataracts, fin rot). Specific sources of PAHs in the river include dumping of oily wastes and creosote and combustion of fossil fuels. TBT was also detected at high levels and is attributed to TBT-containing antifouling paint applied to commercial and recreational watercraft. However, these paints has been banned. The report concluded that industrial and municipal wastewater discharge and urban runoff are the major sources of pollutant loadings to the river. Urban runoff is especially important in the South Hampton area, and as residential, commercial, and office space development increase in this area, control measures will be needed. In addition, monitoring efforts, including a mobile bioassay laboratory and a comprehensive long-term water quality monitoring/sediment contamination program, have been initiated. Further information regarding the identification of urban runoff sources to the Chesapeake Bay is provided in the stormwater section of this chapter.

2.1.3 San Francisco Bay (Region 9)

The Regional Monitoring Program (RMP), established in 1992, is a large-scale trace substance monitoring effort for San Francisco Bay. Participants in the program include numerous POTWs, local stormwater management agencies, the U.S. Army Corps of Engineers, Pacific Gas and Electric, and other industries (SFEI, 1995). The objective of the RMP is to answer questions about the state of the Bay including the level of pollution and if conditions (water quality, organism health, etc.) are improving or getting worse. During 1994, water, sediment, and/or bivalve tissue samples were collected from 24 stations. However, not all parameters were measured at all stations at all times in all three media.

Results of the 1994 effort identified PCB concentrations above WQC at all stations. Levels of total copper, mercury, and nickel were often above WQC, as were concentrations of PAHs and p,p'-DDE. In addition, diazinon was above the National Academy of Science guideline of 9,000 ppq at three freshwater stations. Efforts have been made to identify sources of these pollutants to the Bay. Seasonal differences in concentrations helped narrow down potential sources. Dissolved zinc and total selenium, for example, were higher in February and April, indicating runoff as the likely source. Conversely, pollutants detected during the dry season can be tied to continuous sources, such as riverine sources, waste discharges, atmospheric deposition, or mobilization from sediments. PAHs detected in sediments were attributed to automobile exhaust. The RMP will continue efforts to identify sources in future investigations.

An example of another regional receiving water monitoring effort is the compilation of diazinon data in the San Francisco Bay Area. Several Bay Area cities have identified diazinon as a pollutant of concern (Moran, 1995). Alameda County conducted toxicity testing that linked diazinon levels of 0.1 to 3 μg/L in local creeks to *Ceriodaphnia* toxicity (Hansen, 1995). Maximum diazinon levels in Palo Alto creeks were measured at 0.39 μg/L, with typical values ranging from 0.5 to 2 μg/L (Moran, 1995). A compilation of data from approximately 200 samples collected by several Bay Area cities found diazinon in most Bay Area creeks. Concentrations ranged up to about 3.3 μg/L, with typical values in the 0.1 to 0.3 μg/L range. The Palo Alto RWQCP and the Central Contra Costa Sanitary District have conducted source identification studies for diazinon, which are discussed in the stormwater section of this chapter.

2.1.4 Santa Monica Bay (Region 9)

The Santa Monica Bay Restoration Project recognized that an accurate assessment of pollutant impacts in the receiving water of the Bay was necessary to establish defensible long-term reduction targets (McDonald, 1996). In addition, it was determined that both loading estimates and sediment quality objectives must be established for pollutants that accumulate in the Bay's sediment. A first step of the assessment involved monitoring of water quality, sediment, and biota to determine pollutants of concern. Monitoring of these media in intertidal, open, wetland, lagoon, marina, and harbor locations of the Bay revealed 19 pollutants of concern, including DDT, PCBs, PAHs, chlordane, TBT, cadmium, chromium, copper, lead, nickel, silver, zinc, pathogens, TSS, nutrients, trash and debris, chlorine, oxygen demand, and oil & grease. Table 2-3 lists the pollutants identified at each sampling location along with the observed impacts.

Table 2-3. Pollutant Impacts to Santa Monica Bay

Location	Pollutants Identified	Impacts Observed
rocky intertidal areas	pathogens, debris, oil & grease	potential health risk near continually flowing drains (pathogens); aesthetic impacts (debris); toxic impacts from spills
open bay	DDT, PCBs heavy metals	contaminated sediments near municipal outfall sites; elevated fish tissue levels; localized health risks from seafood consumption contaminated sediments near municipal outfalls
wetlands	heavy metals, nutrients, debris	habitat impairment, impaired water quality; rare and endangered species impairment
lagoon	nutrients, pathogens	eutrophication; potential health risk to swimmers; fish kills
marina	Cu, Pb, Zn, PCBs, DDT, chlordane, TBT, chromium, PAHs	impaired water quality; contamination of sediment, water, and biota; chronic sediment toxicity
harbor	heavy metals	contamination of sediment; elevated contamination levels in shellfish

Loading estimates of the pollutants of concern from major point sources to the Bay were established through WWTP monitoring. However, loadings from other sources, including stormwater/urban runoff, atmospheric deposition and advection, were not determined, but they might be significant contributors of some toxic pollutants. Sediments were identified as the only source of banned or restricted chemicals including DDT, PCB, and TBT (McDonald, 1996).

2.2 Stormwater Monitoring and Source Identification

Stormwater monitoring and source identification studies selected for review are listed in Table 2-1 and discussed below. General stormwater monitoring results are presented in the first section, followed by a discussion of specific monitoring programs conducted in the various US EPA regions. New directions in stormwater monitoring are also discussed. Other stormwater monitoring and source identification efforts identified by the project team, but not reviewed in detail, are listed in Appendix C (Table C-1).

2.2.1 General Stormwater Monitoring

An early US EPA effort to characterize stormwater, the Nationwide Urban Runoff Program (NURP), involved analysis of 2,300 runoff samples collected at 28 locations across the U.S. (US EPA, 1983 as cited in Pitt & Field, 1990). Most of the data collected during the NURP study represented residential areas; however, some commercial/light industrial source areas were also sampled. The NURP study targeted priority pollutants including several trace metals and organic compounds . According to NURP results, as summarized by Makepeace, Smith, and Stanley (1995), 31 inorganic contaminants were identified in the stormwater samples. The inorganic chemicals of greatest concern were copper, lead, zinc, nickel, arsenic, beryllium, and cadmium. Over 100 organic contaminants were analyzed for NURP, and over 60 of these contaminants were detected. Groups of organic compounds analyzed included PCBs, PAHs, halogenated aliphatics, halogenated ethers, monocyclic aromatics, phenols and cresols, phthalate esters, nitrosamines, and pesticides. Bis(2-ethylhexl)phthalate and (∝-BHC) were detected most often (20% of samples). Lindane, chlordane, phenanthrene, pyrene, chrysene, pentachlorophenol, and ∝-endosulfan were detected in stormwater and were deemed to be of concern to human health and/or aquatic life. There were no significant differences in the pollutants detected and their concentrations among the 28 cities sampled. Along with NURP results, Makepeace, Smith, and Stanley (1995) presented additional information on urban stormwater quality. Their findings, including pollutants of concern in stormwater and their concentration ranges, NURP detection frequency, and potential sources, are given in Table 2-4.

Table 2-4. Summary of Pollutants Detected in Stormwater Based on NURP Results[1]

Parameter	Concentration Range in Stormwater Runoff (μg/L)	Detection Frequency During NURP (%)	Potential Commercial/Residential Sources
METALS			
Antimony	3.5 - 23.0	13	gasoline, paint pigments, plastics
Arsenic	1.0 - 210	52	laundry products, pesticides, weed killers
Beryllium	1.0 - 49.0	12	combustion of fossil fuels
Cadmium	0.05 - 13,730.0	48	wear & tear of vehicle parts, fertilizers, pesticides, corrosion of galvanized metals
Chromium	1.0 - 2,300	58	corrosion, paints, dyes, ceramics, paper, heating & cooling coils, fire sprinkler systems, pesticides, fertilizers
Copper	0.06 - 1,410	91	wear & tear of vehicle parts, corrosion (roofs, pipes etc.), fungicides, pesticides
Cyanide	2.0 - 33.0	23	chemical, biological, & clinical labs
Iron	80.0 - 440,000	NA	corrosion of autobodies & other steel
Lead	20.9 - 1,560	94	wear & tear of vehicle parts
Manganese	7.0 - 3,800	NA	wear of tires & brake pads, fertilizers
Mercury	0.05 - 67.0	NA	dental amalgam
Nickel	1.0 - 49,000	43	corrosion

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Table 2-4, cont. Summary of Pollutants Detected in Stormwater Based on NURP Results [1]

Parameter	Concentration Range in Stormwater Runoff (μg/L)	Detection Frequency During NURP (%)	Potential Commercial/Residential Sources
Silver	0.2 - 14.0	NA	photoprocessing, fungicides, dental, medical, and electrical wastes
Zinc	0.7 - 22,000	94	wear & tear of vehicle parts, corrosion of roofs,etc., galvanized steel, and other metal objects
ORGANICS			
BHC	α-BHC 0.0027 - 0.1 γ-BHC 0.052 - 11.0	20 11	γ-BHC used for commercial and domestic pest control
α-endosulfan	0.1 - 0.2	NA	agricultural and domestic pesticide
PAHs	0.0006 - 60.0 (for all compounds)	10-12 (fluoranthene, naphthalene, phenanthrene & pyrene)	combustion, leaching of creosoted wood products
PCBs	0.027 - 1.1	NA	leaching lubricants
Pentachlorophenol	1.0 - 115	15	wood preservative products

[1] SOURCE: Makepeace, Smith, and Stanley, 1995

NURP also included flow rates from storm drain outfalls during or following extended dry periods (i.e., dry-weather flow), and attributed this to possible illicit connections. To address these flows, US EPA developed a User's Guide for investigating inappropriate entries to storm drainage systems (US EPA, 1993). The User's Guide provides an investigative procedure for municipalities and other agencies that is helpful in identifying the most significant sources of non-stormwater pollutant entries into storm drainage systems (US EPA, 1993). In general, the procedure involves identification of contaminated outfalls, followed by an investigation of the associated drainage areas to identify sources, and development of controls once sources have been determined.

A background study, in which non-stormwater outfall discharges were examined, was conducted in conjunction with the development of the User's Guide (US EPA, 1993). This three-phase project was conducted to identify stormwater pollutants and sources (Phase 1), investigate the control of toxics in stormwater (Phase 2), and investigate source area control (Phase 3). During Phase 1, sampling was conducted in various source areas during different rain conditions. This sampling methodology allowed for evaluation of the impacts of different land uses and rain characteristics on pollutant concentrations. Samples were collected from parking areas, storage areas, roof runoff, street runoff, loading docks, vehicle service areas, landscaped areas, urban creeks, and detention ponds. Results revealed the presence of 13 organic compounds in more than 10% of the samples, with 1,3-dichlorobenzene and fluoranthene occurring with greatest frequency. Concentrations of organic compounds were highest in samples of roof runoff, parking areas, and vehicle service areas. Metals were detected in nearly all of the samples. Maximum concentrations of various metals were observed in different land use areas. For example, zinc was highest in roof runoff samples, nickel was highest in parking and storage areas, and cadmium and lead were elevated in samples from vehicle service areas and street runoff. Selected numerical results from Phase 1 of this study are presented in Table 2-5.

Phase 2 of this study involved an assessment of treatment processes using bench-scale testing (Pitt et al., 1993). The objectives of Phase 2 were to identify the most toxic source areas and determine relative toxicity improvements for various stages of each bench-scale treatment method. The Microtox® screening test was used to rate the toxicity of the samples. Parking areas, CSOs, and storage areas had the largest percentage of samples rated extremely toxic. According to Pitt et al. (1993), Phase 3 will use information from Phase 2 to develop a prototype treatment device to control runoff from automobile service facilities.

Table 2-5. Mean Concentrations in Stormwater Samples (Non-Filtered/Filtered)
(Based on Pitt et al., 1995)

Parameter	Mean Concentration (μg/L)								
	Roof areas	Parking areas	Storage areas	Street runoff	Loading docks	Vehicle service areas	Landscaped areas	Urban creeks	Detention ponds
METALS									
Aluminum	6,850[a] 230[b]	3,210 430	2,320 180	3,080 880	780 18	700 170	2,310 1,210	620 190	700 210
Cadmium	3.4 0.4	6.3 0.6	5.9 2.1	37 0.3	1.4 0.4	9.2 0.3	0.5 0.6	8.3 0.2	2 0.5
Chromium	85 1.8	56 2.3	75 11	9.9 1.8	17 ND	74 2.5	79 2.0	62 1.6	37 2.0
Copper	110 2.9	116 11	290 250	280 3.8	22 8.7	135 8.4	81 4.2	50 1.4	43 20
Lead	41 1.1	46 2.1	105 2.6	43 2.0	55 2.3	63 2.4	24 1.7	20 1.4	19 1.0
Nickel	16 ND	45 5.1	55 87	17 ND	6.7 1.3	42 31	53 2.1	29 2.3	24 3.0
Zinc	250 220	110 86	1,730 22	58 31	55 33	105 73	230 140	10 10	13 14
ORGANICS									
Chlordane	1.6 ND	1.0 ND	1.7 ND	0.8 ND	ND ND	0.8 ND	ND ND	ND ND	ND ND
1,3-dichlorobenzene	52 20	34 13	16 14	5.4 3.3	ND ND	48 26	29 5.6	93 ND	27 21
Fluoranthene	23 9.3	37 2.7	4.5 ND	0.6 0.5	ND ND	39 3.6	13 1.0	130 ND	10 6.6

[a] Top value represents non-filtered sample result [b] Bottom value represents filtered sample result ND = Not detected

Another national effort was the evaluation of the effect of snowmelt on the quality of stormwater runoff (Oberts, 1994). Pollutants contributed from snowmelt can either occur from short-duration small quantity "pavement melt" or from more substantial end-of-season melt of the snowpack. Meltwater at the end of the season carries pollutants that have accumulated all winter in the snowpack and also gathers pollutants from street and soil surfaces. Pollutants in the snowpack are a result of atmospheric fallout, industrial activity, vehicular emissions/corrosion/fluid leaks, roadway deterioration, urban litter, and anti-skid grit and chemical deicers. In addition, rain events occurring simultaneously with end-of-season snowmelt can contribute substantial pollutant loads (i.e., greater than summer thunderstorms). Various studies have shown snowmelt runoff to be an important source of pollutants in Minneapolis-St.Paul, Minnesota; Durham, New Hampshire; Denver, Colorado; and Milwaukee, Wisconsin (Oberts, 1994). Constituents of concern identified in these studies include COD, TSS, nutrients, lead, chloride, oil & grease, and total zinc.

2.2.2 Monitoring Programs by US EPA Region

In 1990, in a report to Congress, the US EPA presented the National Water Quality Inventory. This report demonstrated that approximately one-third of U.S. waterways were impaired by stormwater runoff; subsequently, the US EPA published final regulations requiring stormwater permits for large municipalities and urban areas (> 100,000 population), and eleven categories of industry. A primary element of the municipal permits is the characterization of stormwater quality. The goal of permit-required stormwater monitoring data collected as part of this program is to determine the typical runoff quality from residential, commercial and industrial land use areas as well as identify particular sources of runoff pollutants (NCTCOG, 1996). Examples of municipal stormwater monitoring programs implemented across the country are discussed in the following sections organized by US EPA region.

2.2.2.1 NY/NJ Harbor (Region 2)

A recent study was conducted in the NY/NJ Harbor area to evaluate trace metals in CSO discharge and wet weather influent samples from sewage treatment plants (Battelle Ocean Sciences, 1994). The New York City Department of Environmental Protection (NYCDEP) collected six CSO and 23 influent samples during wet weather conditions. In addition, the New Jersey Department of Environmental Protection and Energy (NJDEPE) collected two CSO samples. Samples were analyzed for TSS, particulate carbon (PC), dissolved organic carbon (DOC), total silver, cadmium, copper, mercury, lead, nickel, and zinc. All of the metals were detected in the influent and CSO samples and several measurements were above WQC (as stated in the report). Zinc, lead, and copper, for example, exceeded WQC of 58 μg/L, 8.5μg/L, 2.9 μg/L, respectively in all samples. The maximum zinc and lead concentrations, 1,575 μg/L and 1,383 μg/L respectively, were observed in CSO samples. The maximum copper concentration, 499μg/L, was detected in plant influent. Sources of these metals were not determined during the study.

2.2.2.2 Chesapeake Bay (Region 3)

Commercial and residential sources discharging pollutants of concern to Chesapeake Bay have been identified as point sources (municipal), stormwater runoff, atmospheric deposition, pesticide mixing and loading facilities, household hazardous wastes, and agricultural and domestic pesticide application (Chesapeake Bay Program, 1994). Stormwater runoff was identified as the greatest source of metals loadings to the Bay, followed by point sources and atmospheric deposition. The greatest source of organic chemicals (PAHs and PCBs) and pesticides was determined to be atmospheric deposition, followed by stormwater runoff. The pollutants of concern measured in stormwater runoff were determined to be from a number of sources. Incomplete fossil fuel combustion, especially from wood and coal burned in residential home heating units, is a source of chrysene, fluoranthene, phenanthrene, pyrene, arsenic, and nickel. Automobile related activities contribute significant amounts of cyanides, cadmium, and zinc. Chromium, lead, zinc, and pentachlorophenol are components found in exterior paints and stains. Bis-(2-ethylhexyl) phthalate is a widely used plasticizer for garden hoses, floor tiles, plastic containers, and food packaging. Finally, corrosion of metal alloys contributes cadmium, chromium, copper, and zinc. Other potential sources that have not yet been evaluated are bulkheads, piers and pilings built with pressure treated (copper arsenate) wood, runoff from marina facilities, and antifoulant paint leachates, all of which can cause localized impacts.

Another stormwater investigation in the Chesapeake Bay Area included a modeling project to determine the loadings of ten pollutants present in urban runoff to Chesapeake Bay (Cohn-Lee & Cameron, 1992). The model was based on local land use data, regional annual precipitation, and local and national stormwater concentration averages. Results demonstrated that contamination of the Bay from urban runoff is comparable, if not greater than, contamination from industrial and sewage sources. However, the model contained a few uncertainties: it did not consider fate and transport, nor did it have detailed site-specific land use and pollutant concentration data. A major conclusion of the study was that more site-specific stormwater monitoring data are needed to make accurate loading estimates.

A monitoring study in Maryland conducted by the Metropolitan Washington Council of Governments determined concentrations of hydrocarbons, PAHs, and trace metals in stormwater runoff samples (water and sediment) collected in standard oil-grit separators (OGS) (Shepp, 1996). The OGSs served five automotive-related land use areas in the Maryland Piedmont. Facilities located in the study areas were gas stations, convenience commercial, commuter parking lots, streets, and residential townhouse parking lots. Gas station runoff had the highest concentrations of hydrocarbons, PAHs, and metals in both water and sediments, followed by convenience commercial and commuter parking lots. Streets and townhouse parking lot concentrations were relatively low. Pollutants were attributed to spillage or leakage of oil, gas, antifreeze, lubricating fluids, cleaning agents and other automotive-related compounds.

2.2.2.3 Wisconsin (Region 5)

Most of the stormwater monitoring in Region 5 has been conducted in the State of Wisconsin. For example, a toxics reduction strategy was established for the Greater Milwaukee Area (MMSD, 1991). One of the goals of the strategy is to improve the Milwaukee Metropolitan Sewerage District (MMSD) database to maximize the effectiveness of the ongoing toxics reduction program and to document progress in achieving toxics reduction goals. Several steps were outlined in order for the MMSD to reach this goal, including researching information from other sewerage districts to identify pollutants of concern (POCs); compiling information on stormwater inflow, residential sources, and commercial sources; developing and implementing a comprehensive monitoring strategy for POCs (including residential and commercial sources); and determining the need for additional stormwater monitoring.

In addition, the State of Wisconsin focused several monitoring efforts on identification of pollutants present in stormwater and the sources of these pollutants. A study conducted by the Wisconsin Department of Natural Resources (DNR) and USGS (Bannerman, Owens, and Dodds, 1993), determined the contaminant loads for representative sources in various study areas. Rainfall runoff samples were collected from various land use areas including residential and commercial locations. Samples were collected within these areas from streets, parking lots, roofs, driveways, and lawns. Streets were an important source of most pollutants in all areas, whereas parking lot runoff was more critical at commercial sites. Roofs in commercial areas were found to contribute significantly to zinc loads. Lawns and driveways in residential areas were reported to produce substantial phosphorus loads.

The USGS and the City of Madison, Wisconsin conducted monitoring and sampling of stormwater runoff from seven drainage basins in Madison from 1993-94 (Waschbusch, 1996). Rainfall and stormwater runoff samples were collected from various land use areas, including commercial, medium-density residential, light industrial, university, highway, and shopping center. Samples were analyzed for metals, pesticides, and semivolatile organic compounds (SVOCs) to determine the quality of storm runoff. Metals detected were arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver and zinc. All of these metals were detected at the commercial, university, and light industrial sites, and all metals except arsenic, selenium, and zinc were detected at all locations. Methoxychlor was the only pesticide detected at any of the sampling locations (a maximum concentration of 3.9 $\mu g/L$ was detected at the university location). The SVOCs were only observed at commercial, high density residential, highway, and shopping center locations. Most often detected SVOCs were fluoranthene, phenanthrene, and pyrene. Volatile organics were not detected at any of the sampling sites. The reported numerical data are summarized in Table 2-6.

The impacts of stormwater runoff on urban streams in Milwaukee County, Wisconsin, were observed during another Wisconsin DNR study (Masterson and Bannerman, 1994). To determine the impacts, storm sewer outfalls, stream water quality, bottom sediment, whole fish and crayfish tissue, semipermeable polymeric membrane devices (SPMDs), benthic macroinvertebrates, and habitat quality were monitored. Chemical analysis results for stream samples were compared with end-of-pipe stormwater data collected by the City of Milwaukee. Receiving water and sediment samples and fish tissue analyses showed high concentrations of several pollutants, including heavy metals, oil and grease, bacteria, and PAHs. The SPMD results illustrated the bioconcentration potential of many of these pollutants. Potential sources of the pollutants were identified as commercial parking lots and highways, industrial sites, residential landscapes and construction site soil erosion. Findings of this study strongly suggest the need for BMPs and other control measures to improve the quality of Milwaukee's urban streams.

Monitoring is also an important aspect of nonpoint source control plans for the Milwaukee River South Priority Watershed Project (Wisconsin DNR, 1991) and the Sheboygan River Priority Watershed Project (Wisconsin DNR, 1993). Monitoring for these two projects helped to identify nonpoint sources, such as construction site erosion and runoff from established urban areas (e.g., freeways, industrial areas, commercial areas, and high density residential areas). Based on the monitoring results, it was determined that residential areas can generate significant quantities of lead, pesticides, and bacteria.

Table 2-6. Stormwater Runoff Data for Madison, Wisconsin 1993–94 [1]

Parameter	Maximum Detected Concentration ($\mu g/L$)						
	Commercial	Medium Density Residential	High Density Residential	University	Light Industrial	Highway	Shopping Center
METALS							
Arsenic	4	ND	4	2	6	ND	ND
Cadmium	2.1	1.1	1.6	0.6	2.2	1	1
Chromium	29	13	19	7	22	8	12
Copper	51	39	466	57	44	55	31
Lead	100	69	109	51	57	54	53
Nickel	44	24	44	51	55	22	32
Selenium	1	3.0	ND	2	4	2	0.8
Silver	0.6	ND	0.5	0.5	0.4	ND	0.4
Zinc	356	160	342	220	392	243	261
PESTICIDES							
Methoxychlor	ND	ND	ND	3.9	ND	ND	ND
SVOCs							
Fluoranthene	16	ND	9	ND	ND	13	2
Phenanthrene	9	ND	5	ND	ND	4	ND
Pyrene	11	ND	6	ND	ND	10	ND
OTHER							
Cyanide (mg/L)	ND	ND	ND	ND	0.026	ND	ND
Oil & Grease (mg/L)	ND	ND	ND	ND	12	ND	18
Phenolics (mg/L)	0.012	0.017	0.014	0.013	0.022	0.024	0.033

[1] SOURCE: Waschbusch, 1996
ND = Not detected

Water quality and aquatic habitat investigations were conducted to determine pollution reduction goals. Pollution reduction goals include a 50% reduction in sediment loading, a 50% to 70% reduction in phosphorus loading, and a reduction in the mass loading of heavy metals from future urban areas. BMPs for urban areas have been established for both of these river basins and include hydrologic alterations and good housekeeping practices (reducing sources of pet waste, road salts, lawn fertilizers, and pesticides). Ongoing water quality monitoring is being conducted to evaluate effectiveness of the programs.

2.2.2.4 Illinois (Region 5)

The Illinois State EPA (IEPA) conducted pesticide monitoring of surface waters in an agricultural watershed to determine the presence of commonly used herbicides and organophosphate insecticides (Moyer and Cross, 1990). Seven herbicides (alachlor, atrazine, butylate, cyanazine, metolachlor, metribuzin, trifluralin), seven organophosphates (chlorpyrifos, diazinon, fonofos, malathion, methyl parathion, phorate, terbufos), and one fungicide (captan) were included in the analysis. Monitoring was conducted from 1985 to 1988 and included collection and analysis of ambient and storm event runoff samples. Atrazine was detected at all surface water sampling locations and had the highest maximum concentration (39 μg/L). High concentrations of atrazine were also detected in the runoff samples (peak concentration of 160 μg/L). Pesticide concentrations during storms were found to depend upon the duration and magnitude of the event. As a result of this study, future monitoring objectives were set by the IEPA, including expansion of storm event intensive monitoring to better characterize occurrence of pesticides and their concentrations in stormwater.

2.2.2.5 Lake Superior (Region 5)

During a USGS monitoring effort, contaminant concentrations in stormwater were determined in several Lake Superior Basin Cities from 1993-1994 (Steuer, Selbig, and Hornewer, 1996). The USGS collected stormwater samples from eight Lake Superior Basin cities (in the States of Michigan, Minnesota, and Wisconsin) to determine the quality of urban runoff entering Lake Superior from urban areas. The eight cities sampled contained various land uses ranging from heavy commercial and industrial to residential dominated areas. The ultimate goal of the monitoring program was to obtain data that could be used to educate cities regarding the specific contaminants present in stormwater and determine whether small communities should be included in the stormwater permitting process. Samples were analyzed for nutrients, metals, and PAHs and the results are presented in Table 2-7.

Table 2-7. Contaminant Concentrations in Stormwater Samples Collected from Lake Superior Basin Cities [1]

Parameter	Median Concentration		
	Michigan	Minnesota	Wisconsin
NUTRIENTS/OTHER (mg/L)			
Calcium	15	8.1	12.2
Magnesium	6	4.5	5
Sulfate	11	7	8
Chloride	12.6	14.3	7.1
TSS	284	646	850
Total solids	325	809	824
Nitrate	0.63	0.33	0.45
Total Kjeldahl Nitrogen (TKN)	2	2.5	1.9
Ammonia	0.185	0.254	0.37
Total phosphorus	0.36	0.6	0.73
METALS (μg/L)			
Arsenic	ND	ND	ND
Cadmium	0.6	1.6	0.7
Copper	130	104	59
Lead	54	116	53
Silver	2.3	ND	ND
Zinc	135	325	195
ORGANICS (μg/L)			
Total PAH	5.9	31.27	10.9

[1] SOURCE: Steuer, Selbig, and Hornewer, 1996

2.2.2.6 Galveston Bay (Region 6)

As part of the Galveston Bay National Estuary Program (GBNEP), characterization of nonpoint sources and loadings were determined for the Bay (GBNEP, 1992). Key study components were nonpoint source load calculation, subwatershed ranking, evaluation of upper watershed influences, and mapping. A geographic information system (GIS) mapped the geographic characteristics of the study area, analyzed the land use data, completed nonpoint source estimates, graphically represented results, and helped design pollution control measures. The watershed consists of several land use areas: high-density urban, residential, open/pasture, agricultural, barren, wetlands, water, and forest.

Nonpoint source loads of TSS, total phosphorus, total nitrogen, biochemical oxygen demand (BOD), oil and grease, fecal coliform, dissolved copper, and pesticides were estimated. Loadings were calculated for various scenarios: a year with average rainfall, a year with high annual rainfall, and an individual storm event. High rainfall load calculations were 40% to 60% higher than those calculated for average rainfall. Estimates for a single storm event demonstrated that a significant amount of the annual loads occur during a few large rainfall events per year. High density urban land use areas contributed the greatest nonpoint source loads of all parameters. Major potential sources identified for each of the parameters analyzed are presented in Table 2-8.

Table 2-8. Major Potential Nonpoint Sources of Pollutants to Galveston Bay Watershed

Parameter	Potential Nonpoint Source
TSS	eroding urban areas, cultivated fields, streambanks
Total nitrogen	eroding soils, fertilizer application, leaking sanitary sewers, overflows, by-passes, natural organic matter
Total phosphorus	eroding soils, fertilizer application, leaking sanitary sewers, overflows, by-passes, natural organic matter
BOD	natural decaying organic matter, leaking sanitary sewers, overflows, by-passes, oil and grease
Oil & grease	motor vehicles
Fecal coliforms	leaking sanitary sewers, by-passes, overflows, pets, cattle, wildlife
Dissolved copper	corrosion of copper plumbing, algicides, eroding soils
Pesticides	urban and rural pesticide application

2.2.2.7 Trinity River Basin—Dallas/Fort Worth (Region 6)

Water quality monitoring of the Trinity River Basin (North Central Texas) has helped to identify pollutants of "concern," "possible concern," and "no detectable concern" in this area (NCTCOG, 1996). To make these determinations, eleven years (1982–1992) of receiving water data were compared to the most stringent Texas surface water quality standards (WQS) published for each stream segment or other appropriate reference. The constituents of concern identified during this study included trace metals, fecal bacteria, nutrients, and dissolved oxygen (DO). The constituents of concern determined via this study have been instrumental in identifying pollutants of concern in stormwater runoff in the Dallas/Fort Worth area.

A cooperative stormwater monitoring program encompassing seven cities in the Dallas/Fort Worth, Texas, area was designed to more effectively monitor stormwater quality than the administration of individual city programs (NCTCOG, 1996). The program involves runoff sample collection at 11 residential, 6 commercial, 9 industrial, and 4 highway sites (highway data were not presented in this report). Samples were checked for 186 constituents; 100 were detected. However, only 48 were detected in more than 10% of the samples analyzed. To determine the pollutants of greatest concern, several criteria were used—frequency of detection, existence of State of Texas surface WQS for the constituent, occasional exceedance of surface WQS, and a report of the constituent being a potential concern in the upper Trinity River and its tributaries. Based upon these criteria, several constituents were deemed priority pollutants of concern for the Dallas/Fort Worth region: cadmium, chromium, copper, lead, zinc, chlordane, diazinon, fecal coliform, fecal streptococcus, and TSS.

Four of the constituents, including TSS, copper, lead, and zinc, were detected in all three land use areas (residential, commercial, and industrial). Future monitoring activities will include sampling of mixed land use and instream sites which are expected to better characterize the urban landscape.

2.2.2.8 Austin (Region 6)

A study involving urban runoff monitoring at several sites operated by the City of Austin, Texas was conducted to examine first flush stormwater pollutants (Chang, Parrish, and Souer, 1990). First flush, a concept introduced in the early 1970s, suggests that most of the urban pollutant load is transported during the beginning of a storm. A general rule was adopted based on this idea that 90% of the annual stormwater pollutant load is transported in the first one-half inch of runoff. Several programs used this rule to develop BMPs. However, this study determined that the first flush rule is not as absolute as previously thought. First flush was found to depend upon the amount of impervious cover. Areas with 70% and 90% impervious cover had 78% and 64%, respectively, of the annual pollutant load present in the first flush. However, the first flush rule (90% of the annual pollutant load in the first flush) did hold true for areas with 50% impervious cover. Another major conclusion of this study was that first flush effects are especially weak or absent for certain pollutants including nitrate, copper, ortho-phosphate, bacteria, and sediment.

2.2.2.9 Iowa (Region 7)

The Iowa Department of Natural Resources utilized information from national and local studies to determine potential impacts of pollutants on Iowa's surface waters (IDNR, 1994). Specific land use areas in Iowa were correlated with pollutants of concern. Residential areas were reported to be a source of pesticides, nutrients, bacteria, and sediment; municipal areas contribute ammonia, metals, oxygen-demanding substances, nutrients, pesticides and oil & grease; agricultural areas add sediment, nutrients, bacteria, and pesticides to Iowa's surface waters. Sources of pollutants in non-stormwater urban runoff were identified as fire hydrant flushing, lawn watering, motor vehicle washing, drains within commercial facilities, non-stormwater connections, and CSOs. A conclusion of this study, based upon current monitoring program data and a review of past investigations, is that Iowa has good to excellent water quality. However, monitoring programs will continue. Levels of PCBs, chlordane, mercury, and cadmium, for example, will be monitored to determine the degree to which urban areas contribute to levels of pollutants in Iowa fish. In addition, the cities of Davenport and Des Moines will continue stormwater monitoring programs and will establish new programs to control stormwater contaminants originating from commercial and residential areas.

2.2.2.10 Bay Area Stormwater Management Agencies Association (Region 9)

The Bay Area Stormwater Agencies Association (BASMAA) consists of representatives from all of the stormwater programs in the San Francisco Bay Area. Several of these programs have been conducting stormwater monitoring programs, including the Santa Clara Valley Nonpoint Source Pollution Control Program (SCVNPS), the Alameda Countywide Clean Water Program (ACCWP), the Contra Costa Clean Water Program (CCCWP), and Vallejo and Fairfield/Suisun city programs (WCC, 1996). Data from these monitoring efforts are compiled and then made available to other BASMAA members to increase the database available for evaluating stormwater issues in the Bay Area. The SCVNPS and ACCWP have been monitoring since 1987 and 1988, respectively, and initially involved characterization of stormwater runoff quality and estimation of annual metal loads to the Bay. Samples were collected at stations that drained different land use areas during wet weather and at waterway stations during wet and dry weather. The CCCWP has been collecting samples since 1994–95 at two waterway stations. The cities of Vallejo and Fairfield/Suisun have conducted stormwater monitoring, but these data have not been added to the BASMAA database.

Samples collected as part of the ongoing SCVNPS and ACCWP are analyzed for total recoverable (and occasionally dissolved) metals, TSS, TDS, hardness, TOC, total oil and grease, VOCs, SVOCs, PAHs, organochlorine pesticides, and chlorinated herbicides. According to the 1996 Monitoring Data Analysis Report, which contains stormwater sample analysis results, most parameters were measured below the detection limits (WCC, 1996). In response to toxicity identification (TIE) findings, both programs recently added monitoring of diazinon and chlorpyrifos. However, results of the diazinon and chlorpyrifos measurements were not presented in the 1996 Monitoring Data Analysis Report.

Metal concentrations detected in SCVNPS and ACCWP waterway samples were hypothetically compared to current regulatory standards for San Francisco Bay, i.e., water quality objectives (WQOs) and water quality criteria (WQC). Chronic and acute WQOs represent criteria for total metals concentrations, whereas the recently adopted WQC are based upon the dissolved metal fraction. When data were compared to WQC criteria, several trends were recognized. For example, more hypothetical exceedances occurred in highly urbanized watersheds than in watersheds with more open space. Concentrations of dissolved copper, lead, and zinc exemplified this observation. In addition, mercury exceeded the chronic WQO and the WQC consistently. However, the hypothetical exceedances are probably related to the criteria being based upon the bioaccumulation potential of mercury. These criteria might not be appropriate for stormwater, because levels do not remain elevated long enough to be accumulated by aquatic species. Dry weather monitoring and fish tissue analysis are needed to validate this hypothesis.

In addition to the sampling describe above, SCVNPS has evaluated the effectiveness of modifications to a detention basin, and ACCWP has collected grab samples in an effort to identify industrial and residential sources of pollutants (WCC, 1996).

2.2.2.11 Ventura County (Region 9)

Stormwater monitoring, as part of the Ventura Countywide Stormwater Quality Management Program (VCSQMP), has been underway in Ventura County, California since 1993 (VCSQMP, 1995b). Runoff samples are collected at two residential land use stations, two industrial stations, one commercial station, two receiving water stations, and one agricultural runoff station. Station locations were selected based on the ultimate goal of characterizing runoff from predominant land uses in the county in order to estimate pollutant loads and refine stormwater management programs. At least three storm events are sampled during each wet season, a first-flush/early-season storm, a mid-season storm, and a late-season storm. Analytical parameters include nutrients, total and dissolved metals, bacteria, and organics. Monitoring results for the urban runoff sites during the 1994–95 wet season are presented in Table 2-9. All of the organic compounds were measured below the detection limit and insufficient data were collected at the agricultural site and receiving water sites during this time to report results. The values in Table 2-9 are similar to NURP values obtained for the same land uses and similar to stormwater monitoring data collected in other communities of California.

In addition, a countywide approach to determine illicit discharges was implemented in 1995 (VCSQMP, 1995a). The program design draws from the US EPA's User's Guide (discussed previously in this chapter) for identifying and determining the sources of illicit discharges. Sources under investigation included sanitary wastewater, septic tank effluent, household chemicals, gasoline filling stations, vehicle maintenance/repair, laundry wastewater, carpet cleaning wastewater, acid wash water, leaking tanks and pipes, miscellaneous process waters, loading docks, motor oil, wet sanding operation runoff, solvents, steam cleaning runoff, outside storage, landscape runoff, and leaking air compressors. Target businesses that contribute to these illicit discharges were identified as gas stations, automobile service facilities, commercial laundries, carpet cleaners, painting contractors, pool cleaning, salvage yards, recycling facilities, restaurants, machine shops, and facilities with outside storage. According to the program description, investigations involving field inspection and testing, were conducted to determine illicit dischargers. Investigations entail visual observations, field tests, and collection of samples for laboratory analysis. Once dischargers have been identified, education and follow-up inspections are initiated.

2.2.2.12 Sacramento (Region 9)

Pesticides, especially diazinon and chlorpyrifos, have been identified as primary pollutants of concern for the Sacramento/Central Valley region. In 1993, the U.S. Geological Service (USGS) studied the movement of diazinon through the Sacramento-San Joaquin delta. Diazinon was applied as a dormant spray pesticide in orchards in the Central Valley in the last two weeks of January, 1993. After a series of rainstorms in early February, diazinon concentrations were measured at different points along the Sacramento and San Joaquin Rivers. Concentrations of diazinon were measured at Freeport (near Sacramento) in the Sacramento River a few days after each rainfall. Diazinon concentrations peaked at 0.39 μg/L after the first rainfall and 0.19 μg/L after a subsequent rainfall. Similarly, concentrations in the San Joaquin River peaked a few days after each rainfall

Table 2-9. Median EMCs Based on 1994–95 Wet Weather Monitoring Data Collected in Ventura County, California

Parameter	Units	Commercial Station	Industrial Station 1	Industrial Station 2	Residential Station 1	Residential Station 2
BOD	mg/L	45.5	40.0	8.0	13.5	22.0
COD	mg/L	155.0	121.0	74.0	87.0	100.0
Oil and Grease	mg/L	5.5	ID	5.0	5.0	4.5
pH	std. units	6.5	6.45	6.7	6.5	6.5
Specific Conductance	µS/cm	65.5	54.5	131.0	65.0	75.0
TSS	mg/L	422.5	69.5	212.0	180.5	122.0
TDS	mg/L	64.0	73.0	60.0	67.0	40.0
Total Hardness	mg/L	41.0	18.0	36.0	29.0	22.0
Nitrogen-Ammonia	mg/L	0.3	0.2	ID	0.25	0.1
Nitrogen-Nitrate	mg/L	0.63	0.77	0.75	0.71	0.41
TKN (Organic Nitrogen)	mg/L	3.25	2.45	1.9	2.65	2.4
Total Phosphorus	mg/L	1.1	0.54	0.44	0.58	0.56
Dissolved Phosphorus	mg/L	0.41	0.26	0.4	0.44	0.45
TOC	mg/L	19.0	27.0	7.8	9.0	13.0
Total Coliform	MPN/100mL	160,000	24,000	30,000	50,000	50,000
Fecal Coliform	MPN/100mL	1,950	300	13,000	5,000	20,500
Fecal Streptococcus	MPN/100mL	24,000	24,000	14,000	50,000	90,000
Total Arsenic	µg/L	6.0	2.0	3.5	2.5	2.0

Table 2-9, cont. Median EMCs Based on 1994–95 Wet Weather Monitoring Data Collected in Ventura County, California

Parameter	Units	Commercial Station	Industrial Station 1	Industrial Station 2	Residential Station 1	Residential Station 2
Dissolved Arsenic	µg/L	1.0	1.0	2.0	1.0	1.0
Total Cadmium	µg/L	1.85	0.65	0.55	0.55	0.3
Dissolved Cadmium	µg/L	0.1	0.6	0.2	0.35	0.1
Total Chromium	µg/L	16.0	10.5	12.95	4.65	2.2
Dissolved Chromium	µg/L	1.85	4.4	2.85	1.5	1.4
Total Copper	µg/L	102.5	16.0	23.0	22.5	15.0
Dissolved Copper	µg/L	12.5	9.5	12.0	9.5	10.0
Total Lead	µg/L	37.0	9.0	14.5	32.0	14.0
Dissolved Lead	µg/L	2.5	3.0	2.0	2.65	2.0
Total Mercury	µg/L	ND	ND	ND	ND	ND
Total Nickel	µg/L	20.5	20.5	21.5	22.0	18.0
Dissolved Nickel	µg/L	15.5	18.5	17.0	19.0	10.0
Total Selenium	µg/L	1.0	ND	ID	ND	ND
Dissolved Selenium	µg/L	ND	ND	ID	ND	ND
Total Silver	µg/L	0.2	0.2	0.2	0.3	ID
Dissolved Silver	µg/L	ND	ND	ND	ID	ND
Total Zinc	µg/L	579.0	95.0	139.5	160.5	91.0
Dissolved Zinc	µg/L	43.5	52.5	44.5	45.0	25.0

"ND" = Not Detected; "ID" = Insufficient Detected data (<50% detected or less than3 values).
Medians were not estimated for parameters with less than 2 detected values
Data below the detection limit were set at the detection limit for estimating medians.

when measured at Vernalis (a site near Modesto). Diazinon concentrations reached a maximum of 1.1 μg/L approximately 2 days after the first rainfall. The movement of a diazinon "pulse" down each river was documented at several points. Where the Sacramento and San Joaquin rivers converge in the delta, diazinon concentrations increased steadily throughout February from 0.035 to 0.15 μg/L. The USGS also monitored pesticide levels from January, 1991, to April, 1994, on the Sacramento River at Freeport and on the San Joaquin River at Vernalis (MacCoy et al., 1995). Diazinon was detected primarily in the winter months each year in both rivers. Concentrations ranged from 0.02 to 0.7 μg/L during the winter months.

As part of a TIE performed on Sacramento and Stockton receiving waters, the Central Valley RWQCB collected samples after storm events during the 1994–1995 winter season and analyzed these samples for chlorpyrifos and diazinon (CVRWQCB, 1996). Toxic levels of chlorpyrifos and diazinon were detected in receiving water samples. The TIE confirmed that both chemicals were contributing to toxicity observed in the receiving waters. From the CVRWQCB's TIE, sources of diazinon in Central Valley urban stormwater were determined, based on reported use data, to be both urban and agricultural (CVRWQCB, 1995). Reported use of diazinon in the Central Valley in 1990 included professional landscape maintenance (33,000 lb), structural pest control (74,000 lb), and agricultural uses (560,000 lb).

Metals levels in Sacramento water bodies have also been evaluated. The County of Sacramento has identified inactive mines as a significant source of pollutants for the Sacramento River Basin (Larry Walker Associates, 1993). Over 800 inactive mines exist in the Sacramento River Basin, and many contribute acid mine drainage to basin surface waters. Acid mine drainage contains acid and heavy metals, such as cadmium, copper, and zinc. Additionally, drainage from cinnabar ore and gold mines can contain significant amounts of mercury. Regulatory actions and control strategies have been implemented to control discharge of heavy metals from the inactive mines within the basin.

2.2.2.13 Puget Sound (Region 10)

In 1990, PTI Environmental Services conducted a pesticide reconnaissance survey of Puget Sound (PTI, 1991). Water samples were collected during high–rainfall precipitation events from four Puget Sound drainages. Sampling was conducted to determine the pesticides present in stormwater runoff. Five pesticides were detected: diazinon, 2,4–D, dicamba, bromacil, and diuron. Diuron exhibited the highest concentrations ranging from 1.3 to 3.3 ug/L. Monitoring results for all of the pesticides detected in water samples are presented in Table 2–10. Future pesticide monitoring efforts were recommended, including routine monitoring, regional reconnaissance surveys, and detailed research studies.

Table 2-10. Pesticide Concentrations Detected in Surface Water of Puget Sound Drainages[1]

Parameter	Concentration Range (μg/L)
2,4-D	0.077–0.54
Bromacil	3.3 (only one detected value)
Diazinon	0.054–0.14
Dicamba	0.11–0.27
Diuron	1.3–3.3

[1] SOURCE: PTI, 1991

2.2.3 New Directions in Stormwater Monitoring

Traditional stormwater monitoring efforts cannot always accurately describe existing conditions in receiving waters, evaluate overall integrity of aquatic communities, or assess the degree of improvement in stream systems. To better characterize urban runoff, stormwater monitoring efforts are expanding their scope to include special studies, BMP effectiveness studies, evaluation of programmatic measures and use of environmental indicators. US EPA's stormwater NPDES permit re-application guidance encourages the use of non-conventional monitoring to make monitoring programs more appropriate and useful to stormwater management decisions (Perciasepe, 1996). US EPA suggests in this guidance that municipalities consider using such non-conventional techniques as habitat assessments, bioassessment, and other biological methods. Examples of new directions in stormwater monitoring are discussed below and include modification to the NCTOG regional monitoring program, special studies in the San Francisco Bay Area, use of volunteer monitoring programs, and development of monitoring programs using environmental indicators.

To meet wet weather characterization requirements for the NCTOG regional monitoring program, 182 stormwater samples were collected at 26 stations in three types of single land use basins between February, 1992, and June, 1993, (Brashear et al., 1995). As part of the permit re-application process, the regional program assessed various monitoring alternatives with the objective of reducing costs and increasing the value of the information gained from the monitoring program. As a result of this assessment, the monitoring program was modified to maintain 14 of the 26 existing single land use sites and to add 7 new sites to monitor mixed land use sites, instream conditions, and undeveloped areas. In addition, two bioassessment projects have been initiated—one in Fort Worth and one in Dallas. The initial program monitored 190 parameters. Less than 30% of these parameters were detected in more than 10% of the samples. To be more cost effective, the parameter set was reduced to 20 parameters. These modifications should focus monitoring efforts more effectively and cut costs.

Several special studies of stormwater issues in the San Francisco Bay Area are being coordinated through BASMAA (Brosseau, 1996). The studies are being conducted by member agencies and the results are tracked and compiled through BASMAA. The special studies are divided into the following categories: impacts on creeks and bays; quality assurance/quality control; source identification and control; BMP evaluation; treatment control measures; and watershed management.

Volunteer monitoring programs are used around the country to encourage public involvement in watershed issues and to enable public agencies to collect more data with limited resources. US EPA has supported volunteer monitoring efforts since 1988 by publicizing such efforts and developing support materials, including monitoring methods manuals and guides to quality assurance project plans (Mayio, 1996). In 1994, 520 volunteer monitoring programs coordinated the efforts of over 350,000 volunteers.

Volunteer data are used by local agencies, as can be seen from the following examples from Minnesota, Maryland, and Tennessee. In Minnesota, volunteers have been collecting lake quality data since 1973 (Mayio, 1996). Planners and government agencies us data reports published by the Minnesota Pollution Control Agency to make decisions on lake management issues, including septic system upgrades, algicide treatments, dredging, and shoreline construction. Maryland's "Save Our Streams" program works with the State Highway Administration to monitor stream conditions before road projects are begun, to assess the impact of road projects on streams, and to determine whether sediment control regulations are being met. The Tennessee Valley Authority Clean Water Initiative was formed in 1993 to identify the causes of water resource problems and form teams of the appropriate people and organizations to address these problems (Lyon, 1996). The Clean Water Initiative teams have developed a framework for using volunteer groups to assist the teams by collecting data. Through this program, volunteers have participated in conducting biological stream assessments through evaluation of fish and benthic communities and riverine habitat quality; monitoring of fecal coliforms at swimming beaches; sediment monitoring by local fisherman of a river that supports trout and small mouth bass fisheries; and monitoring the effectiveness of acid mine drainage BMPs.

The Center for Watershed Protection in cooperation with US EPA has developed a methodology for using environmental indicators in stormwater monitoring programs (Clayton, 1996). Environmental indicators are select parameters and indices that can characterize overall conditions in receiving water and provide baseline information to allow the assessment of stormwater management efforts. Stormwater indicators can be organized into six categories: water quality indicators, physical and hydrological indicators, biological indicators, social indicators, programmatic indicators, and site indicators. Traditional water quality pollutant constituent monitoring is one indicator that can be supplemented with other indicators to develop an overall monitoring strategy. Other stormwater indicators identified by The Center for Watershed Protection are listed in Table 2-11. Monitoring programs incorporating the appropriate indicators can address the information needs of individual municipalities, provide baseline data, and assess the long-term effectiveness of stormwater management programs.

2.3 Monitoring and Source Identification

The project team identified several wastewater monitoring programs focused on commercial and residential sources (Table 2-1). General wastewater monitoring and source identification studies are presented in Section 2.3.1 followed by a discussion of specific monitoring programs conducted in the various US EPA regions.

2.3.1 General Wastewater Monitoring

The US EPA conducted a domestic/commercial loading case study to estimate characteristic pollutant levels in domestic wastewater and wastewaters from specific types of commercial sources (SAIC, 1989). Pollutant levels were determined from existing monitoring data from publicly owned treatment works (POTWs); municipalities were surveyed to obtain information on residential and commercial source monitoring data. Trunk line, specific commercial source, septage hauler, and landfill leachate monitoring data were requested. Approximately 38 POTWs responded to the survey, and all US EPA regions were represented.

Table 2-11. Stormwater Indicator Profile Categories

Major Categories of Environmental Indicators	Indicator Name
Water Quality Indicators	Water quality pollutant constituent monitoring Toxicity testing Nonpoint source loadings Exceedance frequencies of water quality standards Sediment contamination Human health criteria
Physical and Hydrological Indicators	Stream widening/downcutting Physical habitat monitoring Impacted dry weather flows Increased flooding frequency Stream temperature monitoring
Biological Indicators	Fish assemblage Macroinvertebrate assemblage Single species indicator Composite indicators Other biological indicators
Social Indicators	Public attitude surveys Industrial/commercial pollution prevention Public involvement and monitoring User perception
Programmatic Indicators	Number of illicit connections identified/corrected Number of BMPs installed, inspected, maintained Permitting and compliance Growth and development
Site Indicators	BMP performance monitoring Industrial site compliance monitoring

The survey results yielded data on such commercial sources as hospitals, automobile radiator shops, car washes, truck cleaners, photoprocessors, dry cleaners, and laundries. The main objective of the study was to enable POTWs to use these estimated pollutant loadings, in the absence of actual site-specific monitoring data, to calculate local limits. The information was also provided to aid POTWs in identifying commercial sources of pollutants and to help them decide which commercial sources require routine monitoring. As indicated in the report, however, no substitute exists for actual site-specific monitoring data.

The U.S. General Accounting Office (GAO) published a report containing recommendations to US EPA on how to better manage nonindustrial wastewater pollution. The report presents information regarding the range, sources, and seriousness of pollutants found in nonindustrial wastewater; strategies and programs developed by local and State governments to better manage and control these pollutants; and Federal options that might encourage or require better management and control of nonindustrial wastewater pollution (GAO, 1991). Using data collected from US EPA studies, it was demonstrated that household sources—pesticides, drain cleaners, toilet bowl cleaners, degreasers, detergents, gasoline, and motor oil—account for the majority of 12 of the 28 pollutants analyzed. Commercial sources also contribute to wastewater pollution. Data collected from several municipalities were used to determine the pollutants discharged to treatment plants from various commercial businesses. Pollutants that were associated with the different types of facilities are presented in Table 2-12 (US EPA, 1991 as cited in GAO, 1991). The main recommendation of GAO was to require major WWTPs to identify pollutants of concern and their sources and to report on effectiveness of strategies implemented to control pollutants.

Table 2-12. Pollutants Attributed to Specific Commercial Facilities

Type of Facility	Pollutants Discharged
Hospitals	TDS, COD, phosphate, surfactants, formaldehyde, phenol, fluoride, lead, iron, barium, copper, zinc
Radiator shops	COD, zinc, lead, copper
Car washes	COD, zinc, lead, copper
Truck cleaners	COD, TDS, cyanide, phosphate, phenol, zinc, aluminum, chromium, lead, copper
Photoprocessors	silver
Dry cleaners	TDS, COD, phosphate, butyl cellosolve, n-butyl benzene sulfonamide, iron, zinc, copper
Laundries	COD, ethyl toluene, n-propyl alcohol, isopropyl alcohol, toluene, m-xylene, p-xylene, ethylbenzene, bis(2-ethylhexyl)phthlate, iron, lead, zinc, copper, chromium, phosphate, sulfide

2.3.2 Monitoring Programs by US EPA Region

Wastewater monitoring studies conducted by individual municipalities are presented in this section. Municipal pretreatment programs throughout the country conduct residential monitoring in conjunction with development of their local discharge limits. In general, the studies discussed herein have been conducted for purposes other than limits monitoring.

2.3.2.1 Narragansett Bay (Region 1)

Save the Bay, a non-profit organization established to improve Narragansett Bay, has implemented a multi-phase project (Toxic Diet Project) to develop a national model to "improve the quality of the nation's waters by reducing toxic pollution loadings at the source." Phase I of the project involved identification of sources of pollutants and development of a reduction plan for these pollutants, specifically for the town of Northbridge, MA. Copper, lead, and zinc were identified as the pollutants of concern based upon comprehensive sampling conducted by the Northbridge POTW and evaluation of data from other studies. Sources for each of these pollutants were determined during a 1994 study conducted by Save the Bay, which involved sampling of Northbridge's drinking water supply, the drinking water conveyance system, and residential effluent. Copper was the only chemical directly tied to any of the sources sampled; and pipe corrosion was identified as the most significant source of copper. The sampled sources were not significant sources of lead or zinc, suggesting that commercial or industrial discharges are the primary source of these metals (Walsh, 1996).

2.3.2.2 NY/NJ Harbor (Region 2)

A study conducted in the NY/NJ Harbor involved evaluation of PCBs at point sources (Battelle Ocean Sciences, 1993). Ambient river water, and POTW influent and effluent samples were collected and analyzed for low-level PCB concentrations. Influent samples were collected during storm events (i.e., CSO), effluent samples were collected from five area POTWs, and ambient samples were collected from four major tributaries that discharge to the harbor. Samples were analyzed for 50 PCB congeners. Total (sum of all 50 congeners) maximum concentrations for influent, effluent, and ambient samples were 382 ng/L, 96 ng/L, and 25 ng/L, respectively.

2.3.2.3 San Francisco Bay Area (Region 9)

Recently, the San Francisco Bay Area Pollution Prevention Group (SFBAPPG) surveyed POTWs in the San Francisco Bay Area to gather information on toxic organic pollutants (TOPs) in the Bay Area. TOP limits, monitoring data, and studies were requested in the survey. About one-third of the POTWs that responded to the survey have sampled for toxic organic pollutants with most of the TOPs measured below the detection limit. Several of the POTWs, however, reported TOP concentrations that exceeded their permit limits. Tributyltin (TBT) exceeded its permit limit more frequently than any other TOP (Montgomery Watson, 1996b).

Information obtained from the surveys was used to determine the TOPs of greatest concern in the Bay Area. Based upon this data and information from the Ecological Overview of the Estuary Workshop (1995), tributyltin, chlorpyrifos, and diazinon were selected as the TOPs of concern for the Bay Area (LWA, 1996c). A nationwide literature review yielded information on monitoring and sampling studies, environmental impacts, and source identification and control measures for these pollutants (LWA, 1996c). The SFBAPPG will use information presented in this report to coordinate and plan pollution prevention efforts. Some POTWs, namely the City of Palo Alto's RWQCP and the Central Contra Costa Sanitary District (CCCSD), have identified sources of diazinon, and the Palo Alto RWQCP has also determined the source of TBT. The sources of these constituents are discussed in the Palo Alto and CCCSD sections in this chapter.

Copper is a concern for several Bay Area POTWs; therefore the SFBAPPG has also investigated source identification and control strategies for copper in wastewater (LWA, 1994b). The SFBAPPG distributed surveys to pretreatment programs throughout California in an effort to obtain information on copper sources, control strategies, and public education efforts. Copper source data included flows and concentrations of copper in POTW influent and effluent for the industrial, commercial, and residential sectors. Concentrations from each sector varied according to POTW size. For example, medium- and small-sized plants received significant loadings (51% and 87%, respectively) from the residential sector, whereas industry contributed the greatest loadings (67%) to larger plants. Several POTWs reported loadings from specific commercial sources, including auto repair shops, car washing, cooling towers, dry cleaners, laboratories, laundries, medical facilities (hospitals), photoprocessing, printing, radiator repair shops, and universities/schools. The highest average copper concentration was reported for effluent from radiator repair shops—22,337 $\mu g/L$. Average copper concentrations from all of the commercial sources monitored are listed in Table 2-13.

Conclusions drawn from this study include the need for increased sampling of commercial copper sources to further quantify the sources, standardize sampling methodologies, and conduct sampling efforts on a regional basis to obtain larger datasets.

Table 2-13. Copper Concentrations from Various Sources Based on Data from California POTWs

Source	Copper Concentration (μg/L)
Auto repair shops	375
Car washes	179
Cooling towers	91
Dry cleaners	129
Laboratories	120
Laundries	258
Medical facilities(hospitals)	183
Photoprocessors	118
Printers	442
Universities/schools	118

Numerous Bay Area cities have conducted individual studies to determine wastewater pollutants of concern and their sources. Palo Alto, San Jose, Novato, Sunnyvale, and Union Sanitary District (including the cities of Union City, Fremont, and Newark) are a few of the POTWs that have implemented pollution prevention and pretreatment programs to identify and control sources of some or all of the following constituents: arsenic, copper, cadmium, chromium, cyanide, mercury, nickel, selenium, zinc, and tributyltin. Descriptions of the monitoring and pollutant source identification studies conducted by these cities and others are presented in the following sections.

2.3.2.4 City and County of San Francisco (Region 9)

The NPDES permit for the City and County of San Francisco (CCSF) requires CCSF to implement BMPs to control sources of priority pollutants to the combined sewerage system. To develop BMPs, CCSF evaluated the loadings from four major sources: industrial wastewater, commercial wastewater, residential wastewater, and tap water (CCSF, 1993). Commercial facilities were found to contribute over half of the cyanide loadings. Residential sources were found to contribute half of the nickel loadings and almost half of the total mercury loadings. CCSF also conducted a consumer products heavy metals inventory in which the contribution of heavy metals from shampoos, soaps, toilet bowl cleaners, toilet paper, creme rinses, and deodorants was determined (CCSF, 1991). It was found that these products did not significantly contribute to total metals loadings.

In addition, CCSF conducted a survey of households to determine the use and disposal of common household hazardous products (CCSF, 1993b). The survey revealed that motor oil and house paints were used by the majority of residences surveyed. Therefore, CCSF conducted a study to determine the loadings of copper, lead, mercury, nickel, silver, zinc, and cyanide to the sewerage system from San Francisco residents disposing of used motor oil and latex paints to sinks and storm drains, from washing painting equipment in sinks, and from automobiles leaking motor oil onto CCSF streets. The study involved literature reviews on used motor oil and latex paint composition and disposal practices to drains, comparison of the estimated mass loadings from drain disposal and washing operations to dry weather influent data from CCSF's pollution control plant (Oceanside treatment plant), and comparison of the estimated mass loadings from the leaking of used motor oil to the Oceanside treatment plant annual wet weather influent and effluent data. Information gathered during the study suggests that used motor oil is not a significant source of CCSF's current total metals and cyanide influent loadings, i.e., less than 1% of the total metals and cyanide loadings were attributed to used motor oil. Latex paint discharged to sinks and street drains (directly and during washing of painting equipment) was also shown to contribute less than 1% of the total metal and cyanide loadings to the plant. According to the report, CCSF plans to quantify other sources of pollutants of concern including brake pads, tires, and gasoline exhaust.

CCSF conducted a study to determine sources of cyanide to the Southeast Water Pollution Control Plant (SEWPCP) (CCSF, 1992). As part of this study, CCSF evaluated both commercial and residential sources. Commercial wastewater sampling points for the project were determined by reviewing all of the drainage districts in the CCSF to ensure that selected sites were free of regulated industries. Five sampling sites were selected to represent the commercial sector. Additional sampling points were located at selected restaurants in order to estimate the percentage of the cyanide pollutant load from this particular commercial source. Average cyanide concentrations in commercial samples ranged from 5.0 μg/L to 8.6 μg/L, representing 23.8% of the cyanide load, and the contribution from restaurants alone was estimated to range from 2.5 to 19%. In addition, CCSF has inspected and/or monitored automotive service facilities, educational laboratories, medical facilities, photoprocessing labs, and printers and found that none of these businesses discharged detectable levels of cyanide.

In addition, residential streams were sampled at five designated sampling points in CCSF. Average cyanide concentrations in residential samples ranged from 5.0 μg/L to 6.5 μg/L.

In 1991, CCSF's Industrial Waste Pretreatment Program initiated a water pollution prevention program to identify City industries and businesses discharging pollutants that threaten the aquatic resources of the San Francisco Bay and Pacific Ocean (CCSF, 1996). Monitoring is an important part of the program. For example, effectiveness of the program is determined from the analysis of CCSF's two water pollution control plants' influent, effluent and biosolids data, industrial user discharge data, and individual sewerage drainage district discharge data. Monitoring has mostly focused on industrial dischargers, but CCSF has sampled, inspected and permitted several commercial photofinishers, printers, and graphic artists. Once these businesses were regulated by CCSF, the mass and concentration of silver in CCSF's SEWPCP's influent was substantially reduced. The SEWPCP's silver effluent also showed a significant improvement.

In addition, CCSF operates a monitoring program (i.e., City-Wide Collection System Monitoring Program), which identifies and maps all 52 drainage districts that comprise the two major drainage basins from which all wastewater flow is collected and transported to one of CCSF's two treatment plants. Contributory wastewater is sampled on a routine basis. This extensive monitoring program gives CCSF the ability to identify, by contributory district, significant deviations from background concentrations of targeted pollutants and also provides baseline data useful in determining effectiveness of implemented source control strategies (CCSF, 1996).

2.3.2.5 Palo Alto (Region 9)

As required by the NPDES permit, the Palo Alto RWQCP has completed several tasks to achieve compliance with discharge limits for toxic pollutants. For example, the Palo Alto RWQCP has evaluated pollutants of concern, calculated the maximum allowable headworks loadings for the pollutants of concern, conducted a headworks loadings allocation evaluation, and examined pollutants for local limit revision (Montgomery Watson, 1993a,b; 1994a).

A detailed discussion of each of these tasks is beyond the scope of this chapter. However, the Palo Alto RWQCP incorporated this information into their Clean Bay Plan to aid in the identification of wastewater pollutant sources (PARWQCP, 1995). A more recent version of the Palo Alto RWQCP's Clean Bay Plan (PARWQCP, 1996a) outlines the current pollutants of concern, their sources, and control strategies. The pollutants of concern for wastewater are arsenic, chromium, cyanide, nickel, cadmium, copper, mercury, selenium, zinc, and tributyltin, and those for stormwater are cadmium, chromium, copper, diazinon, lead, mercury, nickel, selenium, silver, and zinc. The plan involves continuing monitoring efforts to determine the effectiveness of control strategies and to modify the list of pollutants of concern if necessary. The following is a discussion of some of the source identification investigations conducted by the Palo Alto RWQCP.

Several monitoring efforts have been initiated by the Palo Alto RWQCP to identify sources of copper and perhaps reduce loadings to the plant. Efforts have been focused on corrosion of copper pipes, which is estimated to account for 51% of the copper discharged to the plant (PARWQCP, 1996b). In one study, the copper discharges to the sanitary sewer from the Stanford University Medical Center were evaluated (PARWQCP, 1995). The average amount of copper in the discharge was 0.17 lb/day. Four primary sources were identified including water supply, pipe corrosion, kitchen wastes, and human wastes. It was determined that 75% of the copper from the Center comes from recirculating hot water systems (i.e., pipe corrosion). Recommendations determined from the study were to continue monitoring corrosion and reduce the amount of corrosion with operational changes including reduced temperatures and flow velocities in hot water systems. Technical investigations on copper sources have also been conducted for the Palo Alto RWQCP, including *Linear Polarization Studies and Corrosion Rate Estimates* and *Copper Loading from Cooling Towers and Potable Hot Water Circulation Systems* both produced by Kennedy/Jenks Consultants.

Efforts to identify sources of diazinon have been initiated by the Palo Alto RWQCP, including an investigation of the types and uses of diazinon products registered in California (Cooper, 1996). There are 267 products containing diazinon registered for use with the Department of Pesticide Regulation. These products are classified by formulation type into the following categories: solution/liquid, emulsifiable concentrate, aqueous concentrate, pressurized liquids, sprays, flowable concentrate, dust/powder, wettable powder, granular/flake, impregnated material, and microencapsulated. Sixty of the products are impregnated materials (e.g., flea collars) and were not included in the Palo Alto RWQCP evaluation because they were unlikely to be a source of diazinon in wastewater or stormwater.

Recommended uses are provided on the DPR registry for each product. The indicated uses were divided into indoor and outdoor applications and into commercial and residential applications for the Palo Alto RWQCP study. Most of the products (202 of the 217) have outdoor uses, while the other 15 have only indoor uses. The Palo Alto RWQCP evaluated where each type of formulation is likely to be used. Ninety-six percent of the 72 granular/flake products registered are for outdoor use. Solution/liquid and pressurized spray products are generally used both indoors and outdoors. Over half of the products in the other categories are designated solely for outdoor use. This breakdown of product types might be used to focus source control efforts.

To gain more information about how the product is used, Palo Alto also surveyed retail stores in its service area that sell diazinon (Cooper, 1996). The survey results indicated the following:

- The target pests in the Palo Alto service area are ants, fleas, and grubs;
- Only 29 of the 246 registered diazinon products are available in stores in the Palo Alto service area;
- Formulations in significant use in the Palo Alto service area include granules, dusts, concentrates, and one ready-to-use liquid; and
- Diazinon sales occur primarily in the spring and summer.

Possible sources of tributyltin (TBT), as identified by Palo Alto RWQCP staff, included biocidal cooling water system additives, antifouling paints and stains, protective wood treatments, disinfectant commercial toilet bowl cleaners, and disinfectant carpet and upholstery cleaners (DPR, 1993 as cited in Davidson, 1995). Palo Alto RWQCP staff conducted surveys to determine the potential sources of TBT in the Palo Alto RWQCP service area. Surveys revealed that cooling water system discharge was the most obvious source of TBT (Moran, 1994 as cited in Davidson, 1995). It was calculated that one gallon of 2% TBT solution discharged to the sewer and treated with other wastewater at the Palo Alto RWQCP would contaminate more than 2.4 billion gallons of plant effluent. In addition, the Palo Alto RWQCP determined that even very small discharges from one or two cooling towers using TBT-containing products could cause the plant to violate their TBT effluent limit of 5 μg/L. Control strategies have been implemented to eliminate TBT in cooling water discharge, which are discussed in Chapter 3.0.

2.3.2.6 Novato (Region 9)

The Novato Sanitary District (NSD) established a source monitoring program to determine loadings of seven trace inorganic compounds in wastewater treatment plant influent and in commercial and residential wastewater (LWA, 1996b). Samples were collected from WWTP influent, residential trunk lines, commercial trunk lines, residential tap water, and finished tap water. The following parameters were measured under the Novato source monitoring program (NSMP): copper, lead, mercury, nickel, silver, zinc, cyanide, electrical conductance, pH, temperature, and TSS. Results of the monitoring program demonstrated that copper levels in commercial and residential samples were similar and that the majority (87%) of the copper present in the Novato WWTP influent is from tap water sources. Therefore, source control efforts in commercial and/or residential sectors are not likely to significantly decrease influent copper concentrations. Conversely, lead concentrations in commercial wastewater were significantly higher than either residential or WWTP influent concentrations, and tap water was not a significant source. The majority of mercury in NSD wastewater was unaccounted for; unmeasured non-residential sources accounted for an estimated 40% to 72%. In general, nickel and silver concentrations were higher in commercial wastewater and WWTP influent than in residential samples. In addition, the majority of silver loadings were attributed to non-residential sources. A high percentage (51%) of zinc loadings was attributed to unmeasured non-residential sources. Cyanide was largely undetected and loadings could, therefore, not be estimated.

2.3.2.7 San Jose (Region 9)

An evaluation of pollutant sources was conducted for the City of San Jose (CH2M Hill, 1995). The sources investigated included industry, nonpermitted industry (representing 37,000 commercial businesses in the Water Pollution Control Plant (WPCP) service area), residential, and water supply. Pollutants of concern evaluated in the report were arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel, selenium, silver, and zinc. Zinc represented approximately 75% of the total metals load to the WPCP, with equal amounts contributed from residential and water supply sources. Copper represented the second highest contribution, 9%, with proportionate loadings from all sources. A significant percentage of nickel (59%) and silver (65%) came from commercial sources. Residential areas also contribute substantial silver (19%).

The City of San Jose investigated un-permitted sources of nickel and copper in Santa Clara/San Jose WPCP influent (EOA, 1991). The investigated sources were water supply, corrosion, human excrement, common household products, and commercial industry (automotive, photoprocessing, radiator repair, printing shops, and laundries). All source loadings were determined from existing data and a review of the literature; new site-specific data were not collected. The report was to present estimated loadings for assigning priorities to additional investigations. The majority of copper loading (55%) was reported to originate from the water supply and corrosion of copper plumbing. "Other" potential sources—pesticides, pigments, and medical/laboratory products—were estimated to contribute 29% of the total copper loadings. Nickel loading was mainly from water supply and corrosion (68%) with 13% contributed by commercial facilities.

The 1991 study served as the basis for a copper and nickel source control program for commercial facilities conducted by the City of San Jose (EOA, 1992). As part of the source control program, concentration data were collected from POTWs and summarized based upon the highest average concentrations of copper and nickel for commercial categories. Eleven significant commercial sources of these pollutants were determined: transportation (airports & terminal services), machine shops, hospitals, miscellaneous equipment rental, sheet metal work, lithographics, commercial printing, commercial laundries, dry cleaners, and car washes. Average copper and nickel concentrations determined for each source are summarized in Table 2-14.

Table 2-14. Summary of Copper and Nickel Monitoring Data from Commercial Businesses (Data Obtained from Surveyed POTWs)[1]

Source	Average Concentration (mg/L)	
	Copper	Nickel
Transportation facilities (airports & terminal services)	10.9	0.44
Machine shops	4.2	0.26
Hospitals	0.09	0.21
Misc. equipment rental shops	1.2	0.20
Sheet metal work shops	0.69	0.05
Lithographic	0.13	0.04
Commercial printers	0.44	0.06
Laundries	0.58	0.09
Car washes	0.39	0.15

[1] SOURCE: EOA, 1992

More recently, the City of San Jose developed the "Pollution Prevention Strategy for a Clean Bay" (City of San Jose, 1996). This program involves a commercial/residential sampling program to identify sources of copper, nickel, and cyanide. Current source identification programs are focusing on identification of the unaccounted for 20 to 40% of influent copper and nickel. Thus far, the program has determined that residential and commercial sources contribute significant amounts of copper, but do not add to nickel or cyanide loads. To identify sources of nickel and copper, trunkline sampling is being conducted to trace pollutants upstream of the WPCP. In addition, the largest discharger monitoring program is scheduled to continue through October 1997 and data will provide guidance for pollution reduction strategies.

2.3.2.8 Union Sanitary District (USD) (Region 9)

Union Sanitary District serves the cities of Fremont, Newark, and Union City. USD has collected treatment plant effluent monitoring data and has developed local limits. Based upon this information, copper and nickel were identified as the major pollutants of concern (USD, 1995). Mercury, cyanide, and PAHs were also selected as POCs in the Hayward Marsh NPDES permit, and diazinon was designated as a POC in the EBDA/Alvarado treatment plant NPDES permit. USD is targeting automotive machine shops and printers as the major sources of pollutants of concern. A pollution prevention plan has been established by USD and monitoring is being conducted to evaluate the effectiveness of the program.

2.3.2.9 South Bayside System Authority (Region 9)

Sources and loadings of pollutants of concern in wastewater were determined for the South Bayside System Authority (SBSA) as part of their waste minimization plan (LWA, 1992). The SBSA treats wastewater for the cities of San Carlos, Belmont, Redwood City, and the West Bay Sanitary District. Source identification included analysis of commercial and residential discharges. The following commercial sectors were evaluated: auto repair and auto parts cleaning facilities, radiator repair shops, photoprocessors, printing and publishing companies, laboratories, hospitals, painting contractors, laundries, and cooling towers. Residential sources identified were indoor household products, graywater, outdoor household products, copper sulfate root killer, and human body wastes. Pollutants associated with each commercial and residential source are presented in Table 2-15.

Table 2-15. Commercial and Residential Sources of Inorganic Pollutants as Reported by South Bayside System Authority[1]

Sources of Pollutants for SBSA	Parameter										
	As	Cd	Cr	Cu	Cn	Hg	Pb	Mo	Ni	Ag	Zn
COMMERCIAL											
Auto repair		x		x	x		x		x	x	x
Photoprocessors				x			x			x[2]	x
Commercial printers				x				x		x	x
Hospitals & clinics						x				x	
Dental offices				x						x	x
Labs[3]				x		x			x		
Painting				x	x	x		x			x
Laundries		x	x	x			x				x
Cooling towers				x							x
RESIDENTIAL											
Indoor household products		x	x	x		x	x		x		x
Graywater		x	x	x			x		x		x
Outdoor household products				x		x	x	x			x
Copper sulfate root killer				x							
Human body wastes	x			x		x			x		x

[1] SOURCE: Larry Walker Associates (LWA), 1992.
ND = not determined
[2]Photoprocessing accounts for an estimated 40% of the silver discharged to the SBSA wastewater treatment plant.
[3] Loadings were insignificant for non-medical laboratories, therefore information is for medical laboratories.

2.3.2.10 Central Contra Costa Sanitary District (CCCSD) (Region 9)

The Central Contra Costa Sanitary District (CCCSD) has investigated sources of chlorpyrifos and diazinon (Brandenburg, 1996). Wastewater samples were collected from a residential community and from a number of commercial sources, including self-service pet washes, kennels, and certified pesticide applicators (Table 2-16).

Table 2-16. Sources of Diazinon and Chlorpyrifos
(Brandenburg, 1996)

Source	Chlorpyrifos (μg/L)	Diazinon (μg/L)
Residential	1.8 - 3.0	0.71 - 2.0
Self-service pet washers	0.38 - 7.0	0.045 - 0.099
Certified applicators	0.056 - 1.8	0.035 - 1.1
Kennels	3.1 - 4.8	0.068 - 16

In addition, CCCSD and DPR, with support from USD and Palo Alto, are sampling pesticides to determine the mass contribution to plant influent (Brandenburg, 1996).

CCCSD identified flea shampoos as a significant potential source of chlorpyrifos in wastewater effluent. Estimates were made concerning the number of pet washings that would result in enough insecticide to cause toxicity in the CCCSD effluent (a 35-Mgal/day plant). For flea shampoos containing D-limonene or pyrethrins, between 4,300 and 18,000 pets would have to be washed to put enough insecticide in the sewer system to cause toxicity in the effluent. In contrast, toxicity in the CCCSD effluent would result from washing 2 to 7 pets per day with a chlorpyrifos-containing product.

CCCSD also evaluated residential sources of metals in wastewater (LWA,1994a). The results of this study are discussed in Chapter 4.0.

2.3.2.11 Hayward (Region 9)

The City of Hayward has identified copper, lead, PAHs, and diazinon as pollutants of concern through analysis of influent and effluent monitoring data, review of the proposed San Francisco Basin Plan, new NPDES permit limits, and consideration of composting and beneficial use of POTW solids (Mendoza, 1996). The City evaluated print shops, large service facilities, and residential areas as possible sources of pollutants of concern. Surveys of print shops and large service facilities revealed that these businesses have already implemented effective pollution prevention practices. Therefore, the City decided that targeting these businesses would not result in significant reductions. Residential areas, however, are expected to discharge diazinon and copper and have been targeted through public education programs.

2.3.2.12 Sunnyvale (Region 9)

The City of Sunnyvale WPCP recently updated source loading calculations for the water supply, residential, commercial, and industrial sectors based on monitoring data from 1995 (EOA, 1996). Loadings were determined for copper and nickel, the pollutants of concern determined by the City's local limits development (City of Sunnyvale & EOA, 1993). To determine copper and nickel loadings from the residential sector, tapwater and residential sanitary sewer samples were collected. Tapwater samples were collected to estimate the contribution from corrosion of copper piping and fixtures in households. Based upon 1993–94 tapwater sampling data, the copper concentration from corrosion of residential plumbing was 30 μg/L. This represented a 33% decrease compared to the concentration (45 μg/L) calculated from 1991–92 data. Sanitary sewer lines were sampled in residential areas throughout the City of Sunnyvale during 1995 and were analyzed for copper and nickel. Annual mass loadings were calculated by multiplying the arithmetic mean concentration by the estimated residential flow (3,369 Mgal/yr). Average concentrations for copper and nickel were 0.036 mg/L and 0.006 mg/L, respectively, and mass loadings of 1,012 lb/yr and 169 lb/yr were determined, respectively.

To assess pollutant loadings of copper and nickel from commercial businesses, sewer line sampling was performed in representative commercial areas. Average concentrations of 0.089 mg/L and 0.009 mg/L were determined from the 31 samples analyzed for copper and nickel, respectively. Resulting mass loadings were 632 lb/yr of copper and 64 lb/yr of nickel.

The City also determined mass loadings of copper and nickel from industrial, infiltration and inflow, corrosion (copper only), and groundwater extraction. Calculated mass loadings for each source are presented in Table 2-17. As evidenced in Table 2-16, the residential sector is the largest source of copper (52% of the total) and nickel (47% of the total), and the commercial sector is the second largest source for both metals (33% of the copper and 19% of the nickel). In addition, the City assessed corrosion separately and concluded that, when viewed as a separate source, corrosion is the largest contributor of copper at 58% of the total.

Table 2-17. City of Sunnyvale WPCP 1995 Source Loadings of Copper and Nickel by Source Category
(EOA, 1996)

Source	Copper Mass		Nickel Mass	
	lb/yr	%	lb/yr	%
Water supply	42	2	37	12
Residential	983	52	142	47
Commercial	625	33	58	19
Industrial	221	12	38	12
Other (infil./inflow, groundwater extraction)	38	2	30	10

2.3.2.13 Los Angeles (Region 9)

The City of Los Angeles Department of Public Works, Bureau of Sanitation, conducted a study to mitigate silver, copper, mercury, and zinc in the effluent of the Terminal Island Treatment Plant (TITP) (Bureau of Sanitation, 1994). This study identified sources of silver, copper, mercury, and zinc in the TITP influent in an effort to ultimately reduce concentrations of these metals in effluent discharged to Los Angeles Harbor. Source identification involved sampling and analysis, a literature review, determining removal efficiencies across the plant, and calculation of maximum available headworks loading (MAHL) for each chemical to determine local limits. Sampling results demonstrated that determination of local limits for silver and mercury was not necessary. However, waste minimization programs were established for copper and zinc. Potential sources of copper and zinc were identified as radiator shops, auto shops, and dental offices.

2.3.2.14 Orange County (Region 9)

The sanitation districts of Orange County, California, implemented a nonindustrial source control project to determine the contribution of pollutants from domestic wastewater (County Sanitation Districts, 1995). Sampling was conducted in six residential neighborhoods representing various sociodemographic characteristics. The districts collected data to help determine appropriate local industrial discharge limits. A list of the POCs and their concentrations emanating from each residential source are presented in Table 2-18.

2.3.2.15 Arizona (Region 9)

In 1992, the Arizona Department of Environmental Quality established a navigable water quality standard for arsenic of 3.1 μg/L (Woodwick, 1995). This standard will become applicable to the 91st Avenue wastewater treatment plant (WWTP) (operated by the City of Phoenix) during the current permitting cycle. Several times over the past three years, the WWTP has reported arsenic concentrations above the WQC. In response, the City assessed sources of arsenic (Woodwick, 1995) and determined that a significant amount of the arsenic load emanates from natural and uncontrollable sources. For example, the Verde Formation contributes arsenic to the Verde River, which, in turn, contributes arsenic to the treatment plant. Commercial and residential sources, however, contribute an estimated 83% of the total arsenic load. Several alternatives to resolve the issue of elevated arsenic concentrations were presented by the City. One of the proposed alternatives was to implement a nonindustrial source reduction program and revise the local limit downward to the extent feasible.

In the development of a mercury local limit, the Cities of Phoenix, Glendale, Mesa, Peoria, Scottsdale, Tempe, and the Town of Gilbert identified, surveyed, inspected, and sampled potential mercury dischargers (City of Phoenix, 1995). Sampling was conducted for selected dischargers, including printers, photoprocessors, dentists, hospitals, animal hospitals, laboratories, auto repair shops, auto service stations, funeral homes, lithographics, glass cutters, ceramics, and laundries.

Table 2-18. Concentrations of Pollutants in Domestic Wastewater for the County Sanitation Districts of Orange County[1]

Parameter	Source Concentration (mg/L)					
	upper income-SF[2]	mix of lower income-homes & apts.	middle income-SF	middle & upper income-SF	middle & low income-SF	middle income-SF
NUTRIENTS/OTHER						
Ammonia	27	32	25	26	23	26
BOD	283	424	141	221	159	222
Chloride	372	173	96	266	160	193
TDS	1,345	1,007	584	1,088	858	955
Nitrate	ND	<0.20	<0.20	<0.20	<0.20	<0.20
Nitrite	ND	<0.10	<0.10	ND	ND	<0.10
Oil & grease	ND	<25	ND	ND	ND	ND
Sulfate	270	224	106	286	263	278
TSS	461	495	144	182	158	254
TKN	47	60	34	40	34	40
TOC	95	152	78	85	73	93
METALS						
Antimony	ND	0.001	ND	ND	ND	ND
Arsenic	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Beryllium	ND	ND	ND	ND	ND	ND
Boron	0.37	0.22	0.42	0.34	0.34	0.50
Cadmium	0.0012	0.0019	0.0003	0.0007	0.0005	0.0009
Chromium	ND	<0.003	ND	ND	<0.003	0.010
Copper	0.072	0.08	0.03	0.03	0.04	0.16
Lead	0.001	0.01	ND	0.006	0.001	0.006

Table 2-18, cont. Concentrations of Pollutants in Domestic Wastewater for the County Sanitation Districts of Orange County

Parameter	Source Concentration (mg/L)					
	upper income-SF[a]	mix of lower income-homes & apts.	middle income-SF	middle & upper income-SF	middle & low income-SF	middle income-SF
METALS, cont.						
Mercury	0.0003	0.0006	ND	0.0006	<0.0002	<0.0002
Molybdenum	0.004	0.005	0.002	0.004	0.003	0.004
Nickel	0.005	0.01	<0.001	0.005	0.003	0.15
Selenium	ND	<0.005	ND	ND	ND	<0.005
Silver	<0.002	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND
Zinc	0.12	0.31	0.09	0.19	0.11	0.27
ORGANICS						
1,4-Dichlorobenzene	<0.4	7.6	2.9	1.5	3.2	<0.40
1,1,1-Trichloroethane	<0.21	ND	ND	<0.21	ND	<0.21
2-Butanone	1.2	ND	1.53	ND	ND	ND
Acetone	122	190	111	82	88	91
Bromodichloro-methane	2.1	3.5	0.43	1.6	2.4	1.7
Bromoform	1.8	1.4	0.38	0.67	0.85	0.63
Carbon disulfide	ND	0.99	0.25	0.29	0.63	0.91
Chloroform	3.1	7.9	2.9	1.9	10.7	4.2
cis-1,2-Dichloroethene	ND	ND	<0.13	ND	ND	ND
Dibromo-chloromethane	3.6	4.6	0.88	2.7	3.3	2.6
Ethylbenzene	ND	1.23	0.18	ND	ND	ND

Table 2-18, cont. Concentrations of Pollutants in Domestic Wastewater for the County Sanitation District of Orange County

Parameter	Source Concentration (mg/L)					
	upper income-SF[2]	mix of lower income-homes & apts.	middle income-SF	middle & upper income-SF	middle & low income-SF	middle income-SF
m-Xylene, *p*-Xylene	ND	5.3	0.93	ND	ND	<0.30
o-Xylene	<0.17	0.98	0.36	<0.17	ND	<0.17
Toluene	<0.27	0.46	3.9	<0.27	<0.27	<0.27
4-Methylphenol	20	28	42	29	22	43
Benzoic Acid	80	124	114	105	65	108
Benzyl alcohol	<10	<10	<10	ND	<10	<10
bis(2-ethylhexyl)-phthalate	21	39	23	15	32	23
Butylbenzylphthalate	2.8	3.8	99	<2.1	4.1	2.6
Di-n-butyl-phthalate	ND	ND	16.1	<3.4	<3.4	5.6
Di-n-octyl-phthalate	2.5	3.9	2.1	<2.0	3.4	3.4
Diethyl phthalate	18	18	20	15	13	20
Napthalene	ND	<4.6	ND	ND	ND	ND
Phenol	ND	<2.6	<2.6	<2.6	<2.6	<2.6

[1] SOURCE: County Sanitation Districts of Orange County, 1995.
[2] SF = single family
ND = not detected

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Sampling results demonstrated that dentists discharged the largest amount of mercury to the WWTP. Measurable mercury levels were also detected in wastewater from analytical labs. In response to these findings, BMPs are being developed for dental facilities and analytical labs to reduce mercury loads to the WWTP.

2.3.2.16 Washington (Region 10)

The Municipality of Metropolitan Seattle conducted studies to determine the amount of certain pollutants entering WWTPs from nonindustrial sources. The studies revealed that nonindustrial sources contribute more than 75% of some pollutants (antimony, silver, zinc, diethyl phthalate, di-n-butyl phthalate, butyl benzyl phthalate, chloroform, tetrachloroethylene, and benzene) entering WWTPs (GAO, 1991). Other Seattle treatment plant studies demonstrated that 26% of the total load of arsenic came from powdered laundry detergents, dishwashing detergents, and bleach (GAO, 1991).

CHAPTER 3.0

COMMERCIAL SOURCES OF POLLUTANTS

Some businesses, if evaluated individually, discharge insignificant amounts of pollutants. However, when considered collectively, they can discharge substantial amounts of pollutants. Such commercial sources must be distinguished from industrial sources, which are subject to Federal pretreatment regulations.

Typically, there are many businesses in a community that all conduct the same type of activity (e.g., vehicle service, food service, photoprocessing, etc.). Therefore, these businesses can be addressed more efficiently on a collective, rather than on an individual, basis. Pollution prevention and stormwater programs have targeted several of these business categories as sources of pollutants. This chapter presents general approaches used to address commercial sources and information regarding individual commercial business categories.

3.1 Approaches to Control of Commercial Sources

Strategies used to control commercial sources include permits, zero discharge certification, educational outreach, financial incentives, technical assistance, recognition programs, and certification/training programs. Each of these strategies is discussed briefly below.

3.1.1 Permits

If a business is discharging non-domestic waste to the sanitary sewer system, a wastewater pollution prevention or pretreatment program may choose to allow this discharge. These permits typically have fewer requirements than a standard pretreatment permit, which is used for industrial dischargers. It will likely require the discharger to implement certain BMPs. Permit requirements may also include inspections and sampling, but often these activities are conducted less frequently than for an industrial discharger. The permit is likely to have a low fee or no fee.

3.1.2 Zero Discharge Certification

This strategy is often used in combination with a permit program. If the business can eliminate its non-domestic discharges, then no permit is issued. Many businesses view the option of not being permitted as a strong incentive to review their business practices to see if discharges can be eliminated.

3.1.3 Educational Outreach

Outreach informs the businesses about the pollutant issues, which practices need to be changed, and what alternatives are available. Outreach also informs businesses about new programs with requirements, including permits or zero discharge status. Businesses may also be encouraged to implement BMPs through a nonregulatory approach.

An example of effective business outreach comes from the Seattle Metro program (Carveth, 1993). Seattle has determined that the best publicity for the business community comes from working through existing business formats, such as trade associations and chambers of commerce. These organizations take advantage of the business owner's mindset that "business knows best how to market to business."

Following up on this idea, Seattle has determined that trade shows or trade fair formats are superior to public workshops when applied to the commercial sector. Vendors with products or equipment relevant to pollution prevention set up booths and publicize the event by sending invitations to small business owners. These trade shows are also publicized through local businesses and trade associations. At the trade shows, informative "shop talks" are given on topics of general interest to small businesses and on topics targeting specific industries. The small business trade shows have been held for the last 5 to 6 years, with recent ones having up to 80 vendors and over 1,000 participants.

3.1.3.1 Outreach Materials

The City of Bellevue, Washington, and the San Francisco Bay Area Pollution Prevention Group (SFBAPPG) and the Bay Area Stormwater Management Agencies Association (BASMAA) produce two good examples of outreach materials for vehicle service businesses.

The City of Bellevue program, "Business Partners for Clean Water," developed a manual for automotive businesses. The manual has 5 sections. The first section introduces the Business Partners for Clean Water Program and the Storm and Surface Water Utility. The second section describes how pollutants enter the stormwater and wastewater systems and the impact of these pollutants on local waterbodies. The third section describes pollutants associated with vehicle service facilities and their specific sources and briefly describes BMPs to address these sources. The fourth section describes the BMPs in detail. The fifth section provides the business with a checklist to help identify pollution prevention opportunities at their facility. The manual makes the information necessary to implement BMPs easy to find and easy to follow.

For vehicle service facilities, the SFBAPPG in cooperation with BASMAA developed a booklet, which provides an overview of the BMPs that should be implemented to protect wastewater and stormwater leaving vehicle service facilities (SFBAPPG/BASMAA, 1995). The booklet includes a comprehensive list of BMPs divided into sections dealing with specific activities that take place at vehicle service facilities. To complement the booklet, flyers address single topics in a straightforward style. These flyers were intended to deliver the message simply and assist the service staff in conducting their jobs in an environmentally responsible manner.

3.1.4 Financial Incentives

Financial incentives are used along with other strategies. In many cases, implementation of pollution prevention strategies is cost effective for the business by reducing waste disposal costs and reducing raw materials costs. Publicizing environmentally responsible behavior through recognition programs might also be viewed as a financial incentive if promoted as free advertising and a marketing tool for businesses. Another financial incentive is the use of a 'tiered' permitting system in which different classes of permits have different costs associated with them.

The City of Richmond uses financial incentives to encourage participation in its stormwater programs (Scarpa, 1996). Businesses and apartment complexes are charged a stormwater program fee based on parcel number. Rebates are offered to offset fees based on participation in the City's stormwater program. The business must implement BMPs and educate its tenants concerning the BMPs. In addition, the business is inspected annually and runoff is sampled by the City. Rebates are determined according to how "clean" the business's runoff is. This program is particularly attractive to apartment complexes that represent a large number of parcels and, therefore, have relatively high program fees.

3.1.5 Technical Assistance

Technical assistance is offered to small businesses through "small business assistance centers." Business assistance centers help individual businesses in addition to working with groups of businesses. Centers typically attempt to address all environmental media including air, water, and hazardous waste. They provide the business with information on how to implement certain pollution prevention strategies or BMPs in a cost-effective manner and on how to comply with various environmental regulations. Very often these Centers are associated with a University. Business assistance centers providing materials and information for this project are listed in Table 3-1. Two business assistance centers are described in the following subsections.

Table 3-1. Business Assistance Centers

Business Assistance Center	State	Region
Connecticut Technical Assistance Program	CT	1
Erie County Pollution Prevention Program	NY	2
Virginia Waste Reduction Assistance Program	VA	3
Florida Small Business Assistance Program	FL	4
Industry Environmental Association	FL	4
Pollution Prevention-Waste Reduction Assistance Program	FL	4
Waste Reduction Resource Program	NC	4
Minnesota Technical Assistance Program	MN	5
Iowa Waste Reduction Center	IA	7
Waste Reduction Assistance Program	IA	7
Montana Pollution Prevention Program	MT	8
Pollution Prevention Partnership	CO	8
Sacramento Business Environmental Resource Center	CA	9
Irvine Source Reduction and Technical Assistance Program	CA	9

3.1.5.1 Montana Pollution Prevention Program

The Montana Pollution Prevention Program (MT P2) is a non-regulatory technical assistance program, established in 1992, that works with small businesses and tribes to provide information on pollution prevention (MT P2, 1996). It is located at the Montana State University Extension Service and is funded through a US EPA grant and a grant from the state of Montana. The MT P2 works with all businesses but has targeted certain business types including dry cleaners, vehicle service facilities, printers, the hospitality industry, construction, wood finishing, educational facilities, and the agricultural community. It has developed resource materials, such as fact sheets, videos, and information packets; conducted outreach including workshops and teleconferences; provided on-site technical and research assistance; and worked to create business/government partnerships.

On-site visits were conducted at 28 businesses in 1995 to help businesses implement pollution prevention. Cost effectiveness of pollution prevention practices recommended by the MT P2 was documented for 10 of these businesses (3 dry cleaners, 4 printers, 1 automotive service facility, 1 furniture refinisher, and 1 aircraft business). Pollution prevention practices were implemented at these companies for a total investment of approximately $81,000. Estimated annual cost savings for these 10 businesses totaled $145,000. For examples, practices implemented by printers included replacing isopropyl alcohol (IPA) fountain solutions with low- or no-IPA alternatives, switching to less toxic inks, and converting to a digital prepress process (eliminating the need for photographic processes).

The MT P2 also provides assistance to Native American communities. A 10-week pollution prevention educational module was developed for tribal colleges. The MT P2 hosted the first National Tribal Pollution Prevention Conference with 67 tribes from 29 states represented. They have worked with three reservations to implement an 'environmental justice through pollution prevention' model. The project involves working with representatives from the reservation to conduct a reservation environmental assessment and educational program.

3.1.5.2 Iowa Waste Reduction Center

The Iowa Waste Reduction Center (IWRC) has been in operation since 1988 and is located at the University of Northern Iowa (IWRC, 1995). It is funded through Federal, State,and private funding,including US EPA, the Small Business Administration, and air permit fees. The goal of the IWRC is to help small business owners meet environmental regulations, reduce costs, and protect the environment. IWRC helps businesses with on-site visits and waste assessments. They provide such services as the Small Business Pollution Prevention Center and Mobile Outreach for Pollution Prevention (MOPP). MOPP takes technology and expertise to the small business in a 34-foot mobile unit equipped with the latest pollution prevention equipment. Comprehensive, well-organized guidance and resource manuals have been developed for vehicle service facilities and printers. These manuals address environmental issues for air, water, and hazardous waste. Wastewater and stormwater issues are dealt with effectively. Programs are also conducted with respect to toxic air pollutant studies, air emissions assistance, and a by-product/waste search service.

3.1.6 Recognition Programs

Recognition programs reward environmentally responsible behavior. A business that meets certain requirements is awarded a certificate. The incentive for participation in such a program is that the business' exceptional environmental behavior is publicized. To be effective, the business must perceive that the program offers a competitive advantage. A list of agencies with recognition programs and certification programs (described in the next section) which provided information for this project are listed in Table 3-2. Elements of recognition programs in Palo Alto and Santa Rosa, California are described in the following subsections.

3.1.6.1 Clean Bay Business Program

Palo Alto RWQCP implemented a vehicle service regulatory program in 1992 that targets approximately 330 businesses including auto repair shops, gasoline stations, fleet maintenance facilities, commercial car washes, parts cleaning and repair facilities, and autobody repair shops (Moran, 1995; Uribe, 1995). The program focuses on eliminating discharges to the storm drain and reducing or eliminating discharges to the sanitary sewer.

Businesses are issued permits if they discharge to the sewer. Permits are not necessary for businesses that have eliminated discharges to the sewer. Palo Alto RWQCP has included requirements for vehicle service facilities in their sewer use ordinance. A handbook listing recommended BMPs and explaining how to comply with the ordinance is distributed to all affected businesses. Businesses are visited annually for the purposes of education and inspecting for compliance. In 1994, in addition to the annual inspections, discharge monitoring requirements were implemented for permitted facilities.

Table 3-2. Business Recognition and Certification Programs

Agency	Program	Targeted	State	Region
US EPA	33-50 Program Waste WiSe Water Alliance for Voluntary Efficiency Environmental Leadership Program	Non-specific		
Delaware Department of Natural Resources	Contractor Certification Program	Construction	DE	3
Maryland Department of the Environment	Green Card Certification	Construction	MD	3
Rouge River Program Office	Rouge Friendly Businesses	Vehicle service	MI	5
City of Albuquerque	5 ppm Silver Program	Silver generators, photo processors, jewelers	NM	6
Association of Bay Area Governments	San Francisco Bay Area Green Business Program	Nonspecific	CA	9
BASMAA	Mobile Cleaners Pilot Project	Surface cleaners	CA	9
City of Manhattan Beach	Ocean Safe Enterprises	Construction, vehicle service, restaurants	CA	9
City & County of San Francisco	Green Ribbon Panel	Non-specific	CA	9
City of Santa Rosa, Sonoma Cty.	Sonoma Green Businesses	Vehicle service	CA	9
Palo Alto RWQCP	Clean Bay Business Program	Vehicle service, Auto parts stores	CA	9
San Diego County	Environmental Alliance	Non-specific	CA	9
Alaska Center for the Environment	Alaska Green Star Program	Non-specific	AK	10
City of Bellevue	Business Partners for Clean Water	Construction, vehicle service, restaurants, landscape maintenance, building maintenance	WA	10
City of Olympia	Operation: Water Works	Non-specific	WA	10
King County	Envirostars	Non-specific	WA	10
Seattle Metro	WIN Environmental Achievement Awards	Non-specific	WA	10
Thurston County Nonpoint Pollution Program	Business Pollution Prevention Program	Printers, photoprocessors	WA	10

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Palo Alto RWQCP developed the Clean Bay Business Recognition Program as an incentive for businesses to comply with the vehicle service facility requirements. A business may be designated as a Clean Bay Business based on the results of their annual inspection. Criteria for recognition as a Clean Bay Business are completion of an inspection, compliance with the ordinance requirements, and the lack of significant violations of other environmental regulations. A list of businesses meeting the recognition criteria is circulated to other agencies, including the local fire departments and the County Health Department, to determine if any of these businesses have outstanding violations that might contribute to surface water contamination. Facilities that meet the recognition criteria and receive approval from the other agencies are then designated as Clean Bay Businesses.

Clean Bay Businesses are provided with free advertising tools, such as stickers and placards to be displayed at their facility. In addition, the facilities are recognized publicly through press releases and lists published in the local newspapers.

Of the 330 vehicle service facilities, 55 continue to discharge and are permitted. The remainder have eliminated discharges to the sewer. In 1993, 179 businesses were designated as Clean Bay Businesses in the fall of 1993. Violations of ordinance requirements relating to employee training, spill prevention, and cleanup were found at 98 businesses. Requirements regarding secondary containment for vehicle fluid removal, vehicle washing, and containing vehicle leaks were violated at 39 facilities. Sanitary sewer-related violations were identified at 9 facilities. Of the permitted facilities, 18 businesses exceeded their discharge limits for one or more metals.

3.1.6.2 City of Santa Rosa

The City of Santa Rosa (Grimsrud, 1994) developed and implemented the Compliance Incentive Program (CIP) for the auto repair and service industry targeting approximately 275 businesses. The CIP consists of four elements: technical assistance, regulatory streamlining, recognition, and consumer awareness. Technical assistance takes the form of training and materials regarding BMPs and pollution prevention. A unified inspection checklist, which streamlines the inspection process, was developed through a collaborative effort involving eight regulatory agencies. Businesses that comply with all environmental regulations are presented with a regional sticker recognizing that they are a "Sonoma Green Business." A significant public outreach effort has been initiated to educate consumers about the program and the meaning of the recognition stickers. The CIP is a voluntary program; businesses must request the inspections leading to certification as a Green Business. It is used to supplement a more traditional enforcement program that incudes no-cost permits and annual wastewater discharge inspections. Of 150 inspections conducted during the first year of the program (1994), 33 businesses were found to be in full compliance.

Consumer awareness is viewed as an important element of the CIP. A multi-media campaign to educate the public consists of press conferences, radio ads, TV public service announcements, newspaper articles, public transportation ads, announcements in city billings, public meetings, and school presentations.

Another important component of the CIP is the coordination and communication among the eight regulatory agencies responsible for environmental compliance in Sonoma County. These agencies are the Santa Rosa Industrial Waste Section, Santa Rosa Fire Services, Sonoma County Fire Services, Sonoma County Environmental Health, North Coast Regional Water Quality Control Board, Bay Area Air Quality Management District, Department of Toxic Substances Control, and Cal-EPA. Representatives from these agencies meet once a month to discuss environmental compliance issues and share information on non-complying businesses. The Industrial Waste Section (Pretreatment Program) and the Environmental Health Department have coordinated their inspections to reduce the number of inspections conducted at any one business.

3.1.7 Training and Certification Programs

Training and certification programs are similar to recognition programs in that environmentally responsible behavior is recognized. However, these programs are more formal and require businesses or individuals to demonstrate specific knowledge about BMPs. Customers are then encouraged to only hire certified businesses. Certification programs for the construction industry and for mobile cleaners are described below.

3.1.7.1 Construction Certification Programs

The Maryland Department of the Environment (MDE) implemented a certification program for construction activities in 1980 (Non-Point Source News Notes, 1995a). The program targets earth-moving contractors primarily but has also been conducted for other groups, namely private building companies, land development companies, and the National Park Service. Training is provided by MDE environmental specialists in a 3.5 hour seminar. The training centers around erosion control and the negative impacts of sedimentation. In addition, it educates participants concerning potential erosion issues, such as sediment flow to a storm drain inlet and how inlet protection is used as a control measure. Once the training is completed, each participant receives a “Green Card”. The seminars are typically offered during the winter months when the participants’ workload is light.

To ensure that erosion and sediment control is effectively implemented on construction projects, MDE requires that at least one person on every construction site possess a Green Card. More than 7,000 people have been certified through the Green Card program since its inception. In 1995 alone, 1,350 people were certified as a result of 35 seminars. Although recertification is not required, many Green Card holders do attend additional training seminars.

The Delaware Department of Natural Resources (DNR) implemented a Contractor Certification Program in 1991 that is very similar to the Maryland Program (Shaver, 1993). The DNR regulations require that "responsible personnel involved in the construction project will have a certificate of attendance at an...approved training course." Half-day courses educate contractors about erosion and sediment control. In addition, DNR conducts a more intensive training course (4-day sessions) to certify construction reviewers/inspectors. These certified individuals review and oversee larger construction projects (involving more than 20 hectares) or projects experiencing significant sediment and stormwater problems.

3.1.7.2 Mobile Cleaners Certification Programs

Mobile cleaners (surface cleaners, janitorial services, auto detailers, carpet cleaners, window cleaners) are a significant source of discharges of material, wastes, and polluted waters to storm drain systems in the San Francisco Bay Area. The environmental impact, regulatory liability, and ubiquitous nature of discharges from mobile cleaners make them a seemingly ideal candidate for regulation. Yet, regulators and regulated agencies have found it difficult to address these discharges for several reasons. Consequently, the Bay Area Stormwater Management Agencies Association (BASMAA) has initiated a pilot program to help in breaking through the barriers to regulation and to establish a model for dealing with discharges of this type (Brosseau, 1996).

To develop the surface cleaners’ pilot program, meetings were held with surface cleaners and their customers in which the participants expressed opinions on what would constitute a successful program. The primary opinion was that the customers need educating, as well as the surface cleaners, to establish the value of hiring a responsible surface cleaner. As a result, a program consisting of education and recognition was produced. Surface cleaners that implement the prescribed pollution prevention practices are "recognized" and promoted to potential customers. Recognition is given to surface cleaners who attend an Outreach/Recognition Workshop and take a test based on the workshop contents. Recognition is conferred by BASMAA and the San Francisco Bay Regional Water Quality Control Board through issuance of a "recognition certificate." BASMAA maintains a database of the Recognized Surface Cleaners and provides the list to businesses and agencies that hire surface cleaners. Workshops held in July and November of 1996 resulted in over 200 surface cleaners receiving the certificate.

3.2 Pollution Prevention Control Strategies for Specific Commercial Sources

How the above control strategies are applied to individual commercial sources is discussed in the following section, which presents information on commercial sources for which programs have been developed. For each commercial source, the following elements are discussed:

- Associated pollutants;
- Recommended BMPs; and
- Program elements used to address the business category.

The commercial sources discussed fall into three categories:

- Sources of wastewater and stormwater pollutants;
- Sources of stormwater pollutants; and
- Sources of wastewater pollutants.

Commercial sources discussed in this chapter and pollutants associated with those sources based on information compiled for this report are listed in Table 3-3.

3.3 Sources of Wastewater and Stormwater Pollutants

Businesses with activities that are associated with both wastewater and stormwater pollution are discussed in this section.

3.3.1 Vehicle Service Facilities

Vehicle service facilities engage in many activities that have been linked to both stormwater and wastewater pollution. Pollutants associated with vehicle service activities are metals (particularly copper, zinc, chromium, nickel, and lead), oil and grease, solvents, and PAHs. Activities of concern include vehicle washing, parts and engine cleaning, fluid changing, vehicle fueling, autobody repair and painting, and radiator repair.

Table 3-3. Pollutants Associated with Commercial Sources

Commercial Source	Wastewater or Stormwater	Associated Pollutants
Vehicle service facilities	Both	Metals, oil & grease, nutrients,
Food service businesses	Both	Oil & grease
Painting contractors	Both	Solvents, metals
Construction and new development	Stormwater	Sediment, pesticides, solvents, metals
Boatyards/ marinas	Stormwater	Solvents, engine fluids, sewage, tributyltin
Existing development	Stormwater	Metals, pesticides, nutrients, vehicle fluids
Mobile cleaners	Stormwater	Solvents, metals, oil & grease, detergents
Landscape maintenance	Stormwater	Nutrients, pesticides
Brake pads	Stormwater	Copper, lead, zinc
Laboratories and medical facilities	Wastewater	Mercury, silver, selenium, copper, formaldehyde, phenolics, cyanide, solvents, xylenes, radioactive wastes
Printers	Wastewater	Metals, solvents
Dentists	Wastewater	Mercury, silver
Photoprocessors	Wastewater	Silver, selenium
Jewelry manufacturing	Wastewater	Silver, cyanide, copper
Cooling water systems	Wastewater	Copper, tributyltin, zinc, lead
Machine shops	Wastewater	Metals, oil & grease, solvents
Dry cleaners	Wastewater	Perchloroethylene
Ceramics	Wastewater	Metals, solids
Wood finishers	Wastewater	Solvents, metals

Not only are vehicle service facilities a potential source of several pollutants for both wastewater and stormwater, but most communities have many businesses that fall into this category. For example, Novato Sanitary District with a service area population of 53,000 identified close to 100 businesses that fall into this category (Selfridge, 1996). The Palo Alto RWQCP identified approximately 300 vehicle service facilities in their service area (population 200,000) (Moran, 1995). Even if each business has a relatively small discharge volume, the cumulative effect of all the vehicle service facilities in a community can be significant.

3.3.1.1 Other Vehicle-Related Activities

In addition to businesses that service vehicles (e.g., repair shops, body shops, car washes), other vehicle-related businesses have unique characteristics with respect to stormwater discharges. Two such business categories are auto parts stores and auto salvage yards. In both cases, water pollution from these facilities are primarily stormwater issues. Specific aspects of programs for auto parts stores and automotive salvage yards are discussed below.

Auto parts stores sell products to "do-it-yourselfers" who maintain their own vehicles. Improper use and disposal of these products can result in stormwater pollution. Auto parts stores can help reduce pollution by educating employees and customers concerning proper handling of vehicle parts and fluids (PARWQCP, 1994c). Customers and employees should be encouraged to recycle used fluids. In addition, special attention should be paid to maintenance of parking lots for these stores. Vehicle maintenance in store parking lots should be discouraged. In addition, parking lots should be inspected for drips and puddles and should be swept rather than hosed down for cleaning.

The impact of automotive salvage yards on stormwater quality has also been evaluated (Center for Watershed Protection, 1995). Salvage yards collect wrecked cars, strip them of their parts, and recycle the metal materials, as well as some plastics, glass, and fluids. Industry surveys indicate that over two-thirds of the salvage yards in the U.S. store vehicles outside and that few facilities (less than 20%) drain the vehicles before they are stored. Therefore, these facilities are likely sources of stormwater pollution.

To evaluate salvage yards as a source of stormwater pollution, stormwater runoff samples from over forty storms were analyzed for metals, oil and grease, and phenols over a 10-year period at an automotive salvage yard in Los Angeles (Center for Watershed Protection, 1995). It was determined, based on these data and data from other salvage yards in California, that salvage yards contain typically higher levels of oil and grease, BOD, metals, and some priority pollutants. Copper, lead, and phenols were present in the Los Angeles salvage yard's runoff at levels that cause acute toxicity to aquatic life (e.g., fathead minnows). Certain BMPs were implemented to improve runoff water quality. The primary, non-structural BMP was to drain the fluids from all vehicles prior to stripping or other processing. In addition, an oil-water separator was installed to treat wastewater from the dismantling area of the yard. Additional BMPs were to build a roof over the dismantling area and to build a berm around the dismantling area. Implementation of the these BMPs decreased runoff toxicity from 100% to 14%.

3.3.1.2 Best Management Practices

BMPs have been developed for activities conducted at vehicle service facilities to protect both wastewater and stormwater. The following list of BMPs summarizes the recommended practices used by several programs in the San Francisco Bay Area (SFBAPPG/BASMAA, 1995). They are divided into general practices applicable to most shops and BMPs targeting specific activities.

♦ BMPs for General Practices

Work associated with pollutants should be conducted in properly prepared areas. Whenever possible, work that might generate pollutants should be conducted indoors or under cover to prevent unintentional discharges to the storm drain. The work surface should be nonporous (i.e., concrete floors rather than dirt or asphalt). Absorbant mats should be provided for ourdoor work.

Prevent leaks and spills. Use drip pans to catch leaking fluids or spills. Use secondary containment when storing hazardous materials or hazardous wastes.

Liquid wastes and wastewater should be disposed of properly. Do not discharge toxic pollutants, rinse water or wastewater containing toxic pollutants to the storm drain. Toxic pollutants may only be discharged to the sanitary sewer after necessary treatment processes are installed (e.g., oil-water separators) and approval from the treatment plant is obtained. Non-domestic wastewater and rinsewater should be reused or recycled if possible.

Clean up spills properly. When spills occur, dry cleanup methods should be used. Spill cleanup should be accomplished by vacuuming, sweeping, using rags or dry absorbents first. Once dry cleanup is complete, floors and paved areas may be mopped. Avoid hosing down floors and paved areas.

Dispose of wastes properly. Recycle wastes, such as solvents, paints, oil filters, antifreeze, motor oil, batteries, and lubricants, using separate, well-labeled containers in convenient locations. Label sinks and other drains with reminders to prevent unintentional dumping of toxic pollutants and wastewater.

- BMPs for Specific Operations

Vehicle fluid removal. Conduct operations, such as changing oil, radiator fluids, or other vehicle fluids, in "bermed" or contained areas or use drip pans. Transfer fluids using pumps whenever possible to prevent discharges due to spills or leaks from entering the storm drain or sanitary sewer.

Engine, Parts, and Radiator Cleaning. Use self-contained sinks and tanks, allowing parts to drain and dry over tanks. Rinse parts over hot tanks when possible and use static or countercurrent rinsing to reduce rinse water discharges.

Vehicle Exterior Washing. Recycle wash water by running it through an oil/water separator and reusing it in washing operations. Avoid the use of acid-based or spray-on wheel cleaners. For occasional car washing, take cars to a commercial car wash.

Body Repair and Painting. Carefully calculate paint needs to reduce the amount of waste paint and thinner. Do not use water to control overspray or dust in the paint booth and clean spray guns in a self-contained cleaner. Wastewater emanating from painting operations should not be discharged to the sewer or storm drain.

3.3.1.3 Program Elements

Vehicle service facility programs are based on encouraging businesses to implement the BMPs described above through various control strategies. Strategies often used are permitting, zero discharge certification, recognition programs, and educational outreach. A voluntary program and a permit-based program are described in this section.

City and County of San Francisco (CCSF, 1996). CCSF's Water Pollution Prevention Program has developed a voluntary program for vehicle service facilities. CCSF identified approximately 1,000 vehicle service facilities, including gas stations with repair services, general repair, automotive repair, and glass installation shops. Car washes, although not considered significant industrial users (SIUs), are not included, because they are permitted under CCSF's Pretreatment Program.

Currently, CCSF's vehicle service program is completely non-regulatory. Visits were conducted with the purpose of educating the businesses with respect to pollution prevention opportunities at their facilities. A pollution prevention checklist was used to evaluate the businesses, and the results were shared with the business owner. A binder containing information on recommended practices was provided to each business. These binders contain a letter explaining the vehicle service program, a "Green Wrench Guide" containing BMPs (pollution prevention tips), a regulatory agency matrix, vendors of supplies and services for vehicle service facilities, and a checklist describing how to use and store hazardous materials at vehicle service facilities.

City of Benicia (Gregory, 1995). The vehicle service program in Benicia, California, is a typical example of a permit-based program conducted by a small community. The City of Benicia has 36 businesses that are inspected through their vehicle service program. This includes businesses conducting engine repair, autobody repair, and automotive repair and service. Car washes are permitted in a separate program as minor industrial users (Tier 3 permit) as part of Benicia's pretreatment program. Businesses in the vehicle service program are divided into three categories: businesses having zero discharge, businesses having a steam cleaning operation, and businesses discharging washdown water. Business that are zero discharge do not require permits. Businesses with steam cleaning are required to have an oil-water separator and a Tier 3 permit. Businesses discharging washdown water are not permitted but are required to redirect this discharge to the sanitary sewer eliminating washdown water discharge to the storm drain. Of the 36 businesses, 31 were zero dischargers, 2 had steam cleaning operations, and 3 businesses were discharging washdown water to the storm drain.

Many communities have targeted vehicle service facilities through pollution prevention or stormwater programs. The project team reviewed program information and/or outreach materials targeting vehicle service facilities from over 40 different agencies as listed in Table 3-4.

Table 3-4. Information Collected for Vehicle Service Facilities

Program	Materials Reviewed	State	Region
New England Interstate Water Pollution Control Commission	Brochure, booklet		1
US EPA Region 1	Posters	MA	1
Massachusetts OTA	Program information	MA	1
Narragansett Bay Commission	Program information	RI	1
USEPA Region II Stormwater	Program information	NY	2
Alexandria Sanitary Authority	Program information	VA	3
City of Raleigh	Program information	NC	4
Virginia DEQ	Poster	VA	3
Lee County, Florida	Fact sheets	FL	4
Dade County, Florida	Booklet	FL	4
Rouge Program Office, Michigan	Program information	MI	5
Wisconsin DNR	Fact sheet	WI	5
Minnesota Technical Assistance Program	Fact sheets	MN	5
City of Albuquerque, New Mexico	Fact sheet	NM	6
Iowa Waste Reduction Center	Implementation plan, guidance manual	IA	7
City of Boulder, Colorado	Program information	CO	8
Montana PPP	Program information	MT	8
City of Phoenix	Fact sheets	AZ	9
City of Tempe	Program information	AZ	9
California DTSC	Fact sheet, brochure	CA	9

Table 3-4, cont. Information Collected for Vehicle Service Facilities

Program	Materials Reviewed	State	Region
Palo Alto RWQCP	Recognition program, brochures, reports, ordinance, waste treatment, reports	CA	9
Alameda Countywide Clean Water Program	Booklet, Brochures, Fact Sheets, Posters	CA	9
Santa Clara Valley Nonpoint Source Program	Brochures, booklets	CA	9
City of Livermore	Booklet, brochures, fact sheets	CA	9
San Mateo Countywide Stormwater Pollution Prevention Program	Brochure	CA	9
City of Los Angeles	Fact sheets	CA	9
Union Sanitary District	Fact sheets	CA	9
Sacramento RCSD	Booklet	CA	9
City of Manhattan Beach	RecognitionpProgram, brochure	CA	9
City of Benicia	Permit program	CA	9
Eastern Municipal Water District	Brochure	CA	9
City of Simi Valley	Brochure, booklet	CA	9
Ventura County	Brochure	CA	9
City of Sunnyvale	Booklet	CA	9
City & County of San Francisco	Brochure, inspection program	CA	9
City of San Dimas	Fact seet	CA	9
Sonoma County	Recognition program	CA	9
Novato Sanitary District	Program information	CA	9
Central Marin Sanitation Agency	Program information	CA	9
BASMAA	Brochures, booklets	CA	9
EBMUD	Program information, booklet	CA	9
CCCSD	Program information	CA	9

Table 3-4, cont. Information Collected for Vehicle Service Facilities

Program	Materials Reviewed	State	Region
City of Hayward	Program information	CA	9
Seattle METRO	Brochures, posters	WA	10
City of Bellevue	Guidance manual, booklet	WA	10
King County, Washington	Program information	WA	10
Seattle Drainage and Wastewater Utility	Program information	WA	10
US EPA	Waste Audit Study, guidance manual		
WERF	Guidance manual		

3.3.2 Restaurants and Food Service Businesses

Restaurants and food service businesses (grocery stores, delis, bakeries, etc.) have been targeted by both wastewater and stormwater programs with respect to oil and grease concerns. Other pollutants related to stormwater issues are food wastes and cleaning solutions containing bleaches or detergents. Activities that generate these pollutants include grease handling and disposal, equipment cleaning, spill cleanup, and pavement cleaning, and activities in dumpster and loading dock areas.

3.3.2.1 Best Management Practices

Oil and grease from restaurants are typically handled by installing a grease trap or interceptor. Restaurant BMPs often focus on proper use and maintenance of these items. BMPs are also developed for pavement cleaning, equipment cleaning, spill control, waste disposal, litter control and landscape maintenance. Typical BMPs for restaurants are summarized below and are based on those recommended by the Alameda Countywide Clean Water Program (Alameda County, 1994) and the Ventura Countywide Stormwater Program (VCSQMP, no date).

Oil and Grease Handling. Undiluted cooking oil, grease and meat fats should be recycled by a licensed waste hauler. Large volumes of grease or oily liquids (e.g., salad dressing, sauces) should not be poured down a sink, floor drain, or storm drain. A grease trap or interceptor should be installed and maintained to handle grease residues from cleaning activities.

Interceptor Maintenance. Grease traps and interceptors must be cleaned and maintained regularly to be effective. Licensed companies can provide this service. Traps should not be flushed with hot water or treated with detergents or enzymes. These practices discharge grease to the sanitary sewer.

Pavement Cleaning. Parking lots and paved areas should be swept. If cleaning with detergent is necessary, washwater should be collected and discharged to the sanitary sewer not the storm drain.

Equipment Cleaning. Washwater from equipment cleaning, either indoors or outdoors, should be collected and discharged to the sanitary sewer. This includes washwater from cleaning items, such as dumpsters, floor mats, and exhaust filters.

Spill Control. Prevent spills from entering storm drains or sanitary sewers. Use dry cleanup methods, such as sweeping, rags, or cat litter. If mopping is required, discharge mop water to the sanitary sewer.

Waste Disposal. Dumpster and outdoor waste containers should be covered to prevent stormwater from entering the containers. Dumpsters should be inspected for leaks and repaired or replaced by the leasing company. Paints, pesticides, and cleaners should be disposed of as hazardous wastes.

Litter Control. An adequate number of trash containers should be provided around the facility. Litter should be picked up daily in outside areas particularly near storm drain inlets.

Landscaping. The use of pesticides and fertilizers should be minimized and not at all in wet weather. Yard wastes should be composted or placed in a dumpster. Yard trimmings and waste should not be left in the gutter.

3.3.2.2 Program Elements

Many communities require the BMPs listed in the previous section and will often have ordinances requiring food service establishments to have grease removal devices, such as interceptors. The ordinance is typically enforced by the local wastewater authority through its pretreatment program or pollution prevention program. In addition to materials describing BMPs, outreach will often include information on obtaining and installing interceptors and information on local grease recyclers (LWA, 1996e). Program information and materials collected by the project team for food service businesses are listed in Table 3-5.

Table 3-5. Information Collected for Food Service Businesses

Program	Materials Reviewed	State	Region
Narragansett Bay Commission	Program information, workshop	RI	1
Massachusetts Office of Technical Assessment	Program information	MA	1
Rouge Program Office	Program information	MI	5
City of Boulder	Program information	CO	8
City of Gardena	Brochure	CA	9
City of Glendale	Brochure	CA	9
City of San Dimas	Fact sheet	CA	9
City of Santa Monica	Brochure	CA	9
Eastern Municipal Water District	Brochures	CA	9
Santa Clara Valley Nonpoint Source Pollution	Brochures, booklet, letter, poster	CA	9
Ventura Countywide Stormwater Program	Brochure	CA	9
Alameda County	Brochures, fact sheets, poster	CA	9
City of Simi Valley	Program information	CA	9
California Integrated Waste Management	Brochure	CA	9
Sacramento RCSD	Program information	CA	9
City & County of San Francisco	Source ID report	CA	9
Palo Alto RWQCP	Program information, brochures, interceptor guide	CA	9
City of Fremont, Union Sanitary District	Program information	CA	9
City of Los Angeles	Brochures	CA	9
Los Angeles County	Posters (English and Spanish)	CA	9
City of Manhattan Beach	Recognition program, brochures, guide book	CA	9
San Jose/ Santa Clara WPCP	Brochures, source ID report	CA	9
City of Woodland	Program information	CA	9
King County	Program information	WA	10
City of Bellvue	Guide book	WA	10

3.3.3 Painting Contractors

Latex paints, oil-based paints, and paint additives can cause stormwater or wastewater pollution if not handled and disposed of properly. Paint additives or old paint might contain mercury, lead, or tributyltin. Working with oil-based paints involves the use of thinners and other solvents that should not enter the sanitary sewer or storm drain. Paint removal and equipment cleanup are also activities that can contribute pollutants to wastewater or stormwater. Much of the program information and materials developed for painters is associated with construction activities and discussed in that section Some additional information is discussed in this section.

3.3.3.1 Best Management Practices

The following BMPs are used in outreach to painting contractors by the City and County of San Francisco City (CCSF, no date).

Paint Removal. Burlap sand bags or other barriers should be place around storm drain inlets when power washing is used to remove old paint. Residue from chemical stripping, as well as paint chips and dust containing mercury, lead, or tributyltin, should be collected and disposed of as hazardous waste.

Paint Cleanup. Rollers and brushes need only be cleaned when a job is complete rather than every day. During a job, equipment can be stored in plastic wrap in a cool place so that brushes and rollers remain pliable. When cleaning up, excess paint can be removed by scraping paint into the garbage. Latex paint should be washed off in a sink connected to the sanitary sewer. Oil based paints should be cleaned with thinner or turpentine away from sinks, floor drains, or storm drains. Paint thinner can be re-used by allowing the sediment to settle and decanting the clean thinner into another jar.

Materials selection. Latex paints should be used whenever possible. Organic additives should be used for mildew and algae control, not tributyltin or mercury-containing additives.

3.3.3.2 Program Elements

Some literature has been collected for paint formulators. Program information and materials collected by the project team for painting activities are listed in Table 3-6.

Table 3-6. Information Collected for Painting Activities

Program	Materials Reviewed	State	Region
Dade County	Brochure	FL	4
WLSSD	Source identification report	MN	5
City of Albuquerque	Formulator fact sheet	NM	6
Santa Clara Valley Nonpoint Source Pollution Control Program	Construction BMPs and brochure	CA	9
City of Sunnyvale	Brochure	CA	9
City of Los Angeles	Construction BMPs and brochure	CA	9
Alameda Countywide Clean Water Program	Construction BMPs and brochure	CA	9
City & County of San Francisco	Brochure	CA	9
California DTSC	Formulator fact sheet	CA	9
King County	Program information	WA	10

3.4 Sources of Stormwater Pollutants

Business activities that are conducted primarily outdoors and are typically associated with stormwater pollution are discussed in this section.

3.4.1 Construction

Construction activities are primarily outdoor activities and therefore are a concern with respect to stormwater pollution. Pollutants found in stormwater runoff from construction activities include sediment, paints, solvents, concrete, metals, oil, fuel, fertilizers, and pesticides. Contaminated sediment from construction sites can interfere with reproduction and feeding mechanisms of aquatic organisms and be toxic to certain organisms. High levels of nutrients (i.e., phosphorus, nitrogen) causes excessive growth of algae, which can impair aesthetics, water quality, and recreational use. Other concerns are bacterial contamination, salt contamination and elevated water temperatures (NIPC, 1992).

An emphasis has been placed on developing erosion and sediment controls for construction sites. In addition, construction activities that have been identified as sources of stormwater pollution are:

- Painting, solvent and adhesive application;
- Roadwork and paving;
- Repair and remodeling;
- Landscaping; heavy equipment operation;
- Earth moving activities; and
- Fresh concrete and mortar application.

3.4.1.1 Best Management Practices

BMPs for construction activities are divided into (1) erosion prevention and sediment control and (2) general site maintenance. Typical recommended practices are based on BMPs recommended by BASMAA and the Northeastern Illinois Planning Commission (NIPC, 1992).

- Erosion Prevention and Sediment Control (NIPC, 1992)

  Minimize the area disturbed and the time of disturbance. This is accomplished through effective site planning and design. The smallest area of land should be exposed for the shortest period of time practical during construction. Mass grading (i.e., topsoil removal) should be performed only when construction activities are imminent and should not be performed on areas that will not be constructed during the current season. In addition, development should follow the natural contours of the land whenever possible to create the least potential for erosion. Natural vegetation, such as woodlands, should be preserved whenever possible. This is particularly important for areas immediately adjacent to natural waterbodies and wetlands.

  Stabilize disturbed soils as soon as possible. To minimize erosion, soils should be stabilized within 7 days following the end of active disturbance (grading, construction, etc.). Erosion controls should be implemented and maintained during the entire construction project on all areas not undergoing active disturbance. This includes areas with stockpiled soil and landscape materials. Stabilization is accomplished by protecting exposed soil from the impact of rainfall and from water running off the surface of the land. It is best achieved by re-establishing vegetation through seeding or sodding. Temporary measures also include using mulch or erosion blankets.

Trap and filter eroded sediments before they leave the site. The objective of sediment control is to prevent eroded soil particles from leaving the construction site. The most effective sediment controls reduce runoff velocity and trap runoff allowing sediment to settle out. Eroded sediments are trapped by capturing runoff in a sediment basin and providing sufficient detention time for settling of sediment particles. Eroded sediments can also be filtered by forcing runoff waters to drain slowly through silt fences, straw bale barriers, or vegetated filter strips. Areas that require special attention are storm sewer inlets, culverts, and entrance roads. Storm sewer inlets and culverts should be protected with traps or filters. Roads and parking areas should be stabilized with gravel or the equivalent. In addition, a temporary stone pad with a filter fabric underliner should be installed near the site exit. This device removes dirt and mud and prevents construction vehicle tires from tracking soil onto nearby streets.

Control runoff onto and through construction sites. It is important that runoff from adjacent properties be controlled to prevent water from running across erodible areas. Offsite flow is typically addressed by diverting flow around or through disturbed areas using a stabilized channel and a stabilized outlet. In addition, provisions should be made for increased runoff caused by construction activities.

Routinely inspect construction sites and maintain control measures. Inspections will assess the adequacy of installed erosion and sediment control measures and verify that sediment is not causing onsite or offsite impacts. Maintenance is necessary to assure the continued effectiveness of erosion and sediment control measures.

- **General Site Maintenance (BASMAA, 1995)**

Prevent leaks and spills. Poorly maintained, leaking vehicles and heavy equipment are common sources of stormwater pollution and soil contamination. Site planning, preventive maintenance, and good materials handling can eliminate most spills and leaks. Specific areas well away from storm drains or creeks should be designated for parking and routine maintenance of vehicles and equipment. Maintenance, repair and washing should be conducted offsite if possible or in designated areas onsite. Vehicles and equipment should be routinely inspected for leaks. Drip pans or drop cloths should be used to catch leaks and spills during repair and maintenance activities. Fluids should be collected and recycled when possible.

Clean up spills immediately. Use dry cleanup methods, such as sweeping, absorbent materials or rags, for spilled materials. Spills on dirt areas should be dug up and disposed of properly. Spills should not be washed away or buried. Significant spills should be reported to the appropriate response agency immediately.

Store materials under cover. Wet and dry building materials should be stored under cover and/or surrounded by berms to prevent contact with rainfall and runoff. Containers of paints, chemicals, solvents, and other hazardous materials should be stored with secondary containment and under cover.

Cover and maintain dumpsters. Open dumpsters should be covered with a tarp or plastic sheeting. Dumpsters should be returned to the leasing company for leak repairs and cleaning. In addition to dumpsters, trash cans should be placed around the site to reduce litter on exposed surfaces.

Collect and properly dispose of paint removal wastes. Paint removal wastes include chemical paint stripping residues, paint chips and dust, sand blasting material, and wash water. Dust and paint chips should be swept up or collected in plastic drop cloths. When stripping or cleaning building exteriors with high pressure water, cover or berm storm drain inlets. Wash water should be collected and discharged to the sanitary sewer (if allowed by the local POTW) or onto a dirt area.

Clean up paints, solvents, adhesives, and cleaning solutions properly. Empty, dry paint cans, dry paint, used brushes, dropcloths and rags can be disposed of as garbage. Washwater from cleaning latex painting materials (e.g., brushes, rollers) should be disposed of to the sanitary sewer. Leftover oil-based paints, thinners and solvents can be filtered and reused or recycled. Unwanted paint, thinners, and solvents must be disposed of as hazardous waste.

Keep fresh concrete and cement mortars out of gutters, storm drains, and creeks. Avoid mixing excess amounts of fresh concrete or cement mortar. Wash out concrete transit mixers in designated areas. Washout water should be discharged to settling ponds or onto dirt. It should not be allowed to enter the street, storm drain or nearby waterbodies.

Service and maintain portable toilets. Leaking portable toilets are a potential health and environmental hazard. They should be inspected and maintained routinely and repaired promptly.

Dispose of cleared vegetation properly. Cleared vegetation, tree trimmings, and other plant materials should be composted or taken to a landfill. It should not be disposed of in a creek or drainage facility or left in a roadway where it could clog storm drain inlets.

Use pesticides and fertilizers properly. Do not over-apply pesticides and fertilizers. Follow the manufacturer's instructions for mixing, applying, and disposing of these materials.

Train employees and subcontractors regarding stormwater requirements and individual responsibilities.

3.4.1.2 Program Elements

Federal stormwater regulations require dischargers of stormwater from construction sites to apply for a permit or seek coverage under a promulgated general permit. Several municipalities have developed programs and materials to educate the construction industry regarding regulatory requirements and BMPs that will meet those requirements. Program elements include guidance manuals, brochures describing BMPs, recognition programs, videos, and workshops (Table 3-7).

3.4.2 New Development

New housing developments, roads, and commercial buildings have the potential to generate stormwater pollution through construction activities, post-construction activity, and through the increase in impervious surfaces. Effective planning for new development can address pollutants from parking lots, roads, compacted soils, and other impervious surfaces. Construction activities were discussed in the previous section. Post-construction activities of concern are those activities conducted outdoors on the developed site vehicle service facilities, cleanup for restaurants and food service businesses, painting, and landscape maintenance.

Practices discussed in other sections of this report relating to spill control and covering work areas and trash receptacles reduce the generation of pollutants from these sources. Pollutants generated from impervious surfaces and planning methods to reduce the generation of these pollutants are discussed in this section.

Table 3-7. Information Collected for Construction Activities

Program	Materials Reviewed	State	Region
New Hampshire Department of Environmental Services	Fact sheets	NH	1
Maryland Department of the Environment	Recognition program, brochure	MD	3
Maryland Save-Our-Streams	Brochures	MD	3
Chesapeake Bay Foundation	Report, outreach	MD	3
Delaware DNR	Certification program	DE	3
North Carolina DEM	Guidance document	NC	4
South Carolina DHEC	Guidance manual	SC	4
Northeastern Illinois Planning Commission	Guidance manual, video	IL	5
Minnesota Pollution Control Agency	Guidance manual	MN	5
West Michigan Environmental Action Council	Booklets	MI	5
Rouge River Program Office	Program description	MI	5
Wisconsin DNR	Fact sheets, brochures, letters, forms	WI	5
Louisiana DEQ	BMPs, video	LA	6
North Central Texas Council of Governments	Program description	TX	6
Montana PPP	Program description	MT	8
City of Phoenix	Brochures	AZ	9
Orange County	BMPs, guidance documents	CA	9
City of Manhattan Beach	Brochures, recognition program	CA	9
City of Covina	Flyers	CA	9
Riverside County	Booklets, guide book	CA	9

Table 3-7, cont. Information Collected for Construction Activities

Program	Materials Reviewed	State	Region
City of Los Angeles	Brochures	CA	9
Santa Clara Valley Nonpoint Source Pollution Control Program	Brochures, booklets	CA	9
Palo Alto RWQCP	Contract language, fact sheets	CA	9
California DTSC	Waste audit, fact sheet	CA	9
Sacramento County	Workshops, brochures	CA	9
Mendocino County	Guidance manual	CA	9
Alameda County Clean Water Program	Booklets, brochures, fact sheets	CA	9
Washington State Department of Ecology	Fact sheets	WA	10
Seattle Drainage and Wastewater Utility	Program description , guidance manual	WA	10
US EPA	Guidance document		

Impervious surfaces include rooftops and transport systems (e.g., roads, parking lots, and sidewalks). It has been estimated that transport surfaces constitute as much as 63% to 70% of the total impervious surface in urban and suburban areas (City of Olympia, 1996). In addition, the impervious area associated with medium density, single family homes can range from 25% to 60% depending on the layout of streets and parking areas.

Stormwater pollutants associated with impervious surfaces come from sources, including atmospheric deposition and fluids leaked from vehicles that are washed off the surfaces during storms. Impervious surfaces also elevate water temperatures and decrease biodiversity in streams. (Center for Watershed Protection, 1994).

3.4.2.1 Best Management Practices

Practices to reduce the impact of impervious surfaces include planning and design of new development to reduce imperviousness and practices to maintain impervious surfaces. BMPs based on those developed by the City of Olympia (City of Olympia, 1996) and Orange County (Orange County, 1993) are presented in the following subsections.

- **Planning and Design Recommendations**

  Integrate impervious surface reduction into local policies, goals and regulations, especially with respect to street and parking regulations. Reduce the size of parking areas. Encourage cooperative parking (e.g., park and rides, shared parking) through local policies and provide model legal agreements. Require evaluation of cooperative parking and transportation demand management before approving additional parking. Develop parking standards based on average parking needs instead of peak projections. Build multi-story parking or under the building parking.

  Reduce street coverage. Reduce residential street widths. Retrofit existing cul-de-sacs with vegetated islands designed to hold stormwater.

  Narrow sidewalk widths. Narrow low-use sidewalks to 4 feet in width. Build sidewalks on one side of the street only. Slope sidewalks to drain to vegetated swales or gravel strips.

  Design and locate buildings more effectively. Encourage cluster development that minimizes impervious surfaces. Build and use taller buildings, and modify policies to allow taller buildings.

- **Maintenance of impervious surfaces**

  Maintenance of common areas. Implement trash management and litter control procedures, including litter patrol, emptying trash receptacles, and noting and reporting trash disposal violations by homeowners or businesses. Inspect privately owned catch basins and, if necessary, clean catch basins prior to the storm season (mid-October in California). Streets and parking lots should be swept prior to the storm season.

  Commercial vehicle washing should be done with water only. Vehicle exteriors should be washed with tap water without soap or detergents. Wash water containing soaps and detergents should not enter the stormdrain. Solvents and degreasers can be used for spot cleaning but must be wiped off before the vehicle is rinsed.

Educate property owners, tenants and occupants. Outreach materials concerning general good housekeeping practices and proper use of chemicals should be distributed to homeowners and businesses and other occupants of a development. Outreach materials will differ depending on the type of activity or business (e.g., residential, office commercial, retail commercial, vehicle-related or industrial).

3.4.2.2 Program Elements

Programs for new development have recently been developed by some communities including the City of Olympia, WA and the state of Virginia. The City of Olympia has recently completed an Impervious Surface Reduction Study (City of Olympia, 1996). The goal of the study was to identify and gain community support for future impervious surface reduction techniques that result in increased stormwater treatment and groundwater recharge in the Thurston County region, without causing appreciable increases in development costs.

Based on the City of Olympia's study results, it appears that a 20% reduction in impervious surfaces throughout the study area (North Thurston County Urban Growth Management Area) is achievable. Several recommendations were made as a result of the study with respect to general policy development; vehicle-oriented pavements; construction practices and landscaped areas; design and placement of buildings; and community involvement and education. In particular, several recommendations focused on strategies to reduce the impact of parking areas. Fact sheets were developed regarding alternative, more pervious pavements, and methods of reducing parking. In addition, the City has developed and implemented a parking ordinance aimed at encouraging parking space reduction.

Virginia's new development program is an outgrowth of the Virginia Chesapeake Bay Preservation Act. The Act established a cooperative local government program to protect water quality in the Chesapeake Bay through improved land use management. It requires that development in designated areas meet certain criteria, including minimization of land disturbance, minimization of impervious cover, site plan review for all development, and control of stormwater runoff quality. Under the Act, runoff from redevelopment sites in designated areas must contain 10% fewer pollutants than existed before the redevelopment. Virginia's Stormwater Management Regulations were developed as a result of the Act and require the treatment of the first 1/2 inch of runoff from developments with more than one acre of land disturbance (Bell, 1996).

Program information and materials collected by the project team for new development are listed in Table 3-8.

Table 3-8. Information Collected for New Development

Program	Materials Reviewed	State	Region
City of Alexandria	Program information, reports	VA	3
Southeastern Virginia Planning District	Brochures	VA	3
Center for Watershed Protection	Reports	MD	3
Wright Water Engineers, Inc.	Ski Area Water Quality Mitigation Plan	CO	8
San Francisco Bay RWQCB	Staff recommendations, BMPs, guidance material	CA	9
BASMAA	Guide book	CA	9
Orange County	Guide book, program information	CA	9
Riverside County	Guide book	CA	9
City of Olympia	Study report, ordinance, fact sheets	WA	10

3.4.3 Boatyards/Marinas

Pollutants from boatyards and marinas include paint, wood preservatives, solvents, degreasers, engine fluids, bilge wastes, and boat sewage (SCS Engineers, 1989). The pollutants are generated from hydroblasting (pressure washing) or stripping to remove paint, painting, engine maintenance, bilge pumping, sewage disposal, and onsite spills. Paint removal wastes constitute the major waste problem at boatyards. Hydroblasting yields runoff containing paint chips that can possibly reach adjacent waterways. Chemical stripping produces a toxic sludge that must be disposed of as hazardous waste. Larger boatyards sometimes have sheet metal shops and metal finishing shops to perform specialty repairs.

As mentioned above, paint related wastes are a major concern for boatyards. Numerous monitoring studies have identified TBT-containing antifouling paints, used to control nuisance organisms on the hulls of boats, as a primary source of TBT contamination in harbors, marinas, and other areas of commercial and recreational watercraft activities. Due to the high concentrations of TBT detected and the resulting impacts to aquatic organisms, State and Federal legislation has restricted the use of TBT-containing antifouling paints to control further degradation of coastal habitats (LWA, 1996b).

In mid-1987, several States, including California, Florida, Maryland, Maine, New Jersey, New York, Oregon, Virginia, and Washington, recognized TBT as a problem and implemented restrictions on the use of TBT-containing paints. Most State legislation was modeled after provisions established by the State of Virginia, which included a ban of TBT paints from non-aluminum-hulled boats shorter than 25 m long and a prescribed release rate of TBT no greater than 5 $\mu g/cm^2/day$ (Weis, 1989) State action eventually led to restrictions of TBT antifouling paints at the national level. In 1988, the "Organotin Antifouling Paint Control Act" established restrictions on painting vessels shorter than 25 m (excluding aluminum hulls) and a release rate of TBT no greater than 4 $\mu g/cm^2/day$ (Huggett, 1992). In addition, the Act prohibits the sale, delivery, or purchase of certain organotin antifouling paints and additives and requires continued monitoring and environmental impact assessment in representative coastal areas (33 U.S.C. § 2404 and 2406).

3.4.3.1 Best Management Practices

Most of the BMPs for boatyards and marinas were developed through hazardous waste programs designed to minimize the amount of waste generated and educate workers at these facilities about proper storage, handling, and disposal practices. However, the City of Phoenix and other communities have incorporated BMPs for boat builders and repairers into their stormwater programs due to the close proximity of these facilities to open waterways. The activities to be controlled are addressed by BMPs that have been developed for painters, vehicle service facilities, and machine shops. A summary of the approach taken for boatyards and marinas is presented in the following subsections and is based on work completed by King, Pierce, Snohomish, and Thurston Counties (Small Business Center for Education, 1990) and the City of Phoenix (City of Phoenix, 1996).

Pressure Washing and Surface Preparation. Prevent runoff from hydroblasting and any abrasives, dust, or paint chips from reaching waterways or storm drains. For boatyards without onsite settling tanks, lay tarps around the vessels and sweep up any remaining paint chips after the tarps are removed.

Painting. Train employees on proper spraying techniques. Mix paints in designated areas away from waterways.

Engine Maintenance. Use good housekeeping techniques, clean up spills thoroughly, and properly dispose of any wastes that are generated.

Materials Handling and Disposal. Store materials in protected, secure locations away from drain openings. Provide secondary containment when required. Label containers with correct information regarding the type and characteristics of its content. Do not commingle wastes.

Boat Sewage. Discharge sanitary wastes to a dockside pump-out station that is discharged to a sanitary sewer system or to a commercial waste disposal company. Most marinas provide this service. Another alternative is to arrange for pump-out service provided by commercial 'tank-boats.'

Bilge Water. Bilge water sometimes contains oils and solvents that should not be discharged to the sanitary sewer. Prior to discharge to the sanitary sewer, oil should be decanted. Decanted oil may be disposed at used-oil collection centers. Residual surface oil can be absorbed by an oil-absorbing blanket. Bilge water may then be discharged to the sanitary sewer.

3.4.3.2 Program Elements

Many community programs require implementation of the above BMPs through enforcement of hazardous waste regulations and through pollution prevention programs. To prevent the dumping of boat sewage, there is a Federal law and many State laws that make it illegal to dump untreated sewage into any U.S. water. In Florida, a law was passed to make it easier for boaters to properly dispose of human waste (Florida Clean Vessel Act Grant Program, 1994). Grant funds are being made available to provide pump-out and waste dump stations for every 100 boats. US EPA is also advocating specific strategies to be implemented at existing or new/expanding marinas. These strategies involve new designs for areas that generate pollutants, fish waste management, maintenance of sewage facilities, solid waste management, and public education.

Program information and materials collected by the project team for Boatyards and Marinas are listed in Table 3-9.

Table 3-9. Information Collected for Boatyards/Marinas

Program	Materials Reviewed	State	Region
US EPA	BMPs		
Alliance for the Chesapeake Bay	Fact sheet	VA	3
State of Florida	Florida Clean Vessel Act	FL	4
Lee County Division of Natural Resources	BMPs	FL	4
Broward County	Program information	FL	4
Greater Milwaukee Toxics Minimization	Source identification	WI	5
City of Phoenix	BMPs	AZ	9
Marin County Office of Waste Management	Training kit, workshop materials	CA	9
San Francisco Bay RWQCB	General NPDES permit	CA	9
San Francisco Estuary Project	Guide book	CA	9
California Department of Health Services	Report	CA	9
East Bay Municipal Utility District	Program information	CA	9
Metro	BMPs, poster	WA	10
King County Water Pollution Control	Program information	WA	10
King, Pierce, Snohomish, Thurston Counties	BMPs	WA	10
US Fish and Wildlife Service	Brochure		

3.4.4 Existing Development

Existing development encompasses commercial and residential properties already constructed which might have to incorporate BMPs as retrofits or operational changes. This approach is the opposite of the one used for new developments which may be able to incorporate BMPs into the overall design of the project. Pollutant sources at existing developments include metals in cooling water and boiler discharges, pesticides, and fertilizers from landscape maintenance, vehicle fluids contained in runoff from parking lots and driveways, cleaners and paints used to maintain building exteriors, and chlorinated water from pool and spa maintenance. Activities of concern might be conducted inside or outside the establishment related to the specific type of business undertaken at the site. These activities are addressed in other sections of this report according to the type of business conducted.

3.4.4.1 Best Management Practices

Preventing pollution from existing development involves conserving water, properly maintaining heating and cooling systems, draining pools to the sanitary sewer, disposing of wastes in an appropriate manner, and minimizing runoff and the application of pesticides and fertilizers when maintaining landscape. These BMPs are described in detail in other more applicable sections of this report.

3.4.4.2 Program Elements

Some communities have prescribed BMPs for existing development by producing outreach materials for specific businesses, such as hotels/motels, office buildings, and apartment buildings (PARWQCP, 1995; City of San Jose, 1992a,b). This is a method of reaching those individuals who might not receive general public outreach materials at their residence or might not realize that implementation of BMPs is required at the workplace, as well as at home. Program information and materials collected for existing developments by the project team are listed in Table 3-10.

Table 3-10. Information Collected for Existing Development

Program	Materials Reviewed	State	Region
City of San Jose Environmental Services Dept.	Guidebook	CA	9
Palo Alto RWQCP	Guidebook	CA	9

3.4.5 Mobile Cleaners

The category of mobile cleaners includes all types of cleaning contractors—carpet cleaners, auto detailers, surface cleaners, etc.— who travel to job sites. Usually, wash water is disposed of onsite and often to the storm drain system. These discharges have been found in Fort Worth, Texas, and the San Francisco Bay Area to be a significant source of pollutants to the storm drains. Pollutants include soaps, solvents, lead paint chips, restaurant grease, and vehicle fluids.

3.4.5.1 Best Management Practices

BMPs developed for mobile cleaners are based on the type of surface being cleaned and cleaning method used. Once these criteria are determined, the proper disposal method is specified. For example, if a building exterior is washed without soap and there is no loose paint, disposal to the storm drain may be allowed. In the San Francisco Bay Area, BMPs have been developed for surface cleaners, truck/auto washers, and food-related cleaning activities. A summary of those BMPs are presented below and based on work completed by the Bay Area Stormwater Management Agencies Association (BASMAA, 1996) and the Cleaning Equipment Trade Association (CETA, 1995).

Truck/Auto Washers. Most wash water generated from truck and auto washing must be contained and pumped to the sanitary sewer. Infrequent auto washing runoff may be left to evaporate on the pavement or discharged to landscaped areas. When removing dust from cars with water only, the runoff may be discharged to the storm drain.

Surface Cleaning. If cleaning sidewalks and plazas, unpainted buildings, or painted buildings with no loose paint is conducted without soap, discharge to the storm drain is allowed. However, filtering of the runoff to remove particulates may be required. If soap is used and/or paint is being removed during the cleaning process, the wash water must be contained and discharged to the sanitary sewer.

Food-Related Cleaning. No wash water associated with the cleaning of food-related equipment may be discharged to the storm drains. Runoff from cleaning dumpster areas, floor mats, exhaust filters, grease covered equipment, and lunch wagons/food carts must be discharged to the sanitary sewer system. If no soap is used for cleaning grocery carts, the runoff may go to the storm drains after filtering to remove particles.

3.4.5.2 Program Elements

Many communities have produced outreach brochures to inform mobile cleaning businesses of appropriate methods for wash water disposal. Program information and materials collected for mobile cleaners by the project team are listed in Table 3-11. The City of Fort Worth, Texas, passed a Cosmetic Cleaning Ordinance (Connor, 1996). Discharges to the storm drains are banned unless absolutely no cleaning substances have been added, the storm drain inlet is screened, and no oil sheen is present. Each cosmetic cleaner must have a permit and display the vehicle license registration numbers associated with that permit. The permit holder must ensure that all of its employees are knowledgeable of the discharge prohibitions and are using prescribed BMPs when engaging in cosmetic cleaning activities.

BASMAA initiated a pilot project to control discharges from surface cleaners (Brosseau, 1996). To develop the program, meetings were held with surface cleaners and their customers in which the participants were given a chance to express opinions on what would constitute a successful program. The primary opinion was that the customers need educating, as well as the surface cleaners, to ensure that the value of hiring a responsible surface cleaner is understood. As a result, a program consisting of education and recognition was produced. Surface cleaners who implement the prescribed BMPs are "recognized" by BASMAA and the San Francisco Regional Water Quality Control Board and promoted to potential customers. Recognition is granted to surface cleaners who attend an outreach/recognition workshop and take a self-evaluation exam on the workshop contents. Results of the surface cleaner program are being used as a prototype for developing materials and approaches for the remaining types of mobile cleaners.

Table 3-11. Information Collected for Mobile Cleaners

Program	Materials Reviewed	State	Region
City of Fort Worth	Ordinance, program information	TX	6
Colorado Water Quality Control Div.	Ordinance, program information	CO	8
Bay Area Stormwater Management Agencies Association	BMPs, brochures, program information	CA	9
San Francisco Bay Area Pollution Prevention Group	BMPs, brochure	CA	9
Cleaning Equipment Trade Assn.	BMPs	CA	9
Sacramento Regional County Sanitation District	Fact sheet	CA	9

3.4.6 Landscape Maintenance

Businesses that provide services to plant newly vegetated areas and maintain existing lawns, parks, and public areas can be sources of pollutants, including nutrients and pesticides. Source control strategies for landscape maintenance businesses are similar to those developed for home lawn and garden care and are discussed in Chapter 4.0. Other BMPs are presented in this chapter, under Construction and New Development.

With regard to pesticide use by landscape maintenance businesses, surveys have been conducted to obtain more information on pesticide handling. In Ohio, pesticide applicators were surveyed regarding pesticide application and disposal practices (Ozkan, 1992). Survey results were based on 1,380 responses received from applicators in 18 counties. Over two-thirds of the respondents reported that they calibrate their equipment at least once per year. Over 90% always rinse pesticide containers after emptying them. However, only 71% follow safe rinsing procedures (i.e., triple rinsing, pressure rinsing). Survey respondents indicated the use of several improper disposal methods.

The major portion of outreach material developed for landscape maintenance is directed at the homeowner and the general public. Much of the business outreach targets landscaping in conjunction with construction activities. Program information and materials collected targeting landscape maintenance by the project team are listed in Table 3-12.

3.4.7 Brake Pads

Disc brake pads contain varying amounts of metals including copper, lead, and zinc. Copper content in brake pads can range from less than 1% to as much as 20%. As the brake pad wears, metal dust is generated onto roadways. This dust is washed to storm drains with stormwater runoff. A study conducted by the Santa Clara Valley Nonpoint Source Pollution Control Program estimated that copper from brake pad wear may account for as much as 35% of the copper that enters the San Francisco Bay. While the initial brake pads studies have been conducted in the San Francisco Bay Area, addressing this source at a national level could help address copper pollution problems for water bodies in other parts of the country including the Chesapeake Bay, the New York-New Jersey Harbor, and the San Diego Bay.

Table 3-12. Information Collected for Landscape Maintenance

Program	Materials Reviewed	State	Region
Western Lake Superior Sanitary Dist.	Source identification report	MN	5
Greater Milwaukee Toxics Minimization Task Force	Program information	WI	5
Texas Agricultural Extension Service	Guidebook	TX	6
City of Albuquerque	Brochure for pesticide formulators	NM	6
City of Los Angeles	Brochure	CA	9
City of Sacramento	Brochure	CA	9
City & County of San Francisco	Brochure	CA	9
San Mateo Countywide Stormwater Pollution Prevention Program	Brochure	CA	9
Santa Clara Valley Nonpoint Source Pollution Control Program	Brochure	CA	9
State Water Resources Control Board	Technical report	CA	9
California Department of Toxic Substances Control	Guidebook, fact sheets for pesticide formulators	CA	9
Orange County	Guidebook	CA	9
City of Bellvue	Guidebook	WA	10

An effort to address this source has been initiated through The Brakepad Partnership, formed under the auspices of Common Ground for the Environment (sponsored by Stanford University and Sustainable Conservation). Bay Area organizations provided seed funding. The goal of the Partnership is to identify and implement a voluntary business solution to reduce the levels of copper entering water bodies from brake pads. This solution will be reached through the cooperation of US EPA, California EPA, local governments, community members, automobile manufacturers, brake pad manufacturers, and the makers of friction materials used in brake pads.

Work with brake pads is in its initial stages, and little other information is available at this time.

3.5 Sources of Wastewater Pollutants

Business activities that are typically conducted indoors and associated with wastewater pollution are discussed in this section.

3.5.1 Laboratories and Medical Facilities

Medical facilities have been evaluated as sources of mercury and silver (Rourke, 1988). Hospitals have also been identified as sources of formaldehyde, phenolic disinfectants, selenium, zinc, lead, and cadmium (PARWQCP, Pollution Prevention for Hospitals and Medical Facilities). Specific sources within hospitals include instrumentation and equipment (e.g., temperature and blood pressure measuring devices) as sources of mercury, x-ray and photographic equipment as sources of silver and selenium, cold sterilization and disinfectant solutions as sources of formaldehyde and phenolics.

In addition to specific medical activities, hospitals have laboratory and facilities operations that may also generate certain wastewater pollutants. Laboratories can also be sources of cyanide, copper, solvents, xylenes, and low-level radioactive wastes. Facilities operations include plumbing, laundry, recirculating hot water systems, water softening and purification, and cleaning and maintenance. These activities can be sources of metals.

3.5.1.1 Pollution Prevention for Mercury and Silver

Based on the amount of information available, most communities are concerned with hospitals as sources of silver and mercury. The major source of silver is from x-ray and photographic equipment. BMPs and source control strategies for these areas are discussed in the section of this report entitled Photoprocessing Operations. Another source of silver is silver nitrate solutions used to treat burns. Solutions with high concentrations of silver should be collected and disposed of as hazardous waste.

The primary sources of mercury in medical facilities are equipment, such as measurement devices, lamps and electrical equipment. Proper handling and disposal of mercury-containing equipment should prevent mercury from entering the sanitary sewer. In most cases, alternative products that do not contain mercury are available (Terrene Institute). Mercury thermometers and manometers can be replaced by equipment with electronic sensors. Cantor tubes can often be replaced by Anderson tubes which contain no mercury. Electrical equipment containing mercury can be replaced by solid state devices and fiber optic equipment. Batteries can be replaced by lithium, zinc air or alkaline batteries. There are no effective substitutes for high energy fluorescent lights, but technology is reducing the volume of mercury required in such lights.

Mercury is also present in some laboratory chemicals and pharmaceutical preparations. The amount of mercury in antiseptics, diuretics, and skin preparations is low making these compounds unlikely to be significant sources. For other mercury-containing chemicals however, there are alternatives available.

3.5.1.2 Other Best Management Practices

The BMPs for sources of pollutants (other than silver and mercury) listed below are a compilation of BMPs recommended by Palo Alto RWQCP (PARWQCP, no date, Pollution Prevention for Hospitals and Medical Facilities), City and County of San Francisco (CCSF, 1995a), and the University of Tennessee (University of Tennessee, 1995).

Cold Sterilization. Formaldehyde and glutaraldehyde solutions must be treated and detoxified prior to discharge to the sewer. In certain cases, these solutions may be replaced with peracetic acid.

Laboratories. Wet chemistry methods may be replaced with automated chemical analyzers. Cyanide-free solutions may be available for cell sorting and counting analyzers. Alternatives, such as naphtha isoparaffinic hydrocarbons, may be used in place of xylenes. If xylenes must be used, spent solutions should be recycled and not discharged to the sanitary sewer.

Pharmacy. Neither medicines containing significant levels of metals nor expired medicines should be discharged to the sewer. Chemicals should be clearly labeled.

Utilities and Maintenance. Use automatic injection for laundry and boiler chemicals. Replace single pass cooling systems with recirculating systems. Avoid use of cooling water additives containing tributyltin or copper. Use latex paints instead of oil-based paints. Replace solvents with detergent-based cleaning agents. Replace phenolic disinfectants with quaternary amine disinfectants.

3.5.1.3 Program Elements

Program materials for hospitals have been developed in communities concerned with silver and/or mercury. A list of programs from which program information and materials have been collected by the project team are listed in Table 3-13.

Table 3-13. Information Collected for Hospitals and Laboratories

Program	Materials Reviewed	State	Region
Narragansett Bay Commission	Program information	RI	1
Alexandria Sanitary Authority	Program information	VA	3
Bureau of Solid & Hazardous Waste	Program information	FL	4
City of Raleigh	Program information	NC	4
University of Tennessee	Guide book	TN	4
Terrene Institute	Booklet	IL	5
Western Lake Superior Sanitary District	Report, program information	MN	5
City of Boulder	Program information	CO	8
City & County of San Francisco	Brochures, source ID report	CA	9
Palo Alto RWQCP	Brochures, booklets, poster, checklist	CA	9
California DTSC	Waste audit, Guide book	CA	9
San Jose/ Santa Clara WPCP	Program information	CA	9
City of Los Angeles	Source ID report	CA	9
USEPA	Source ID report		

3.5.2 Printers

The printing industry includes establishments that engage in printing by one or more of the five common printing processes: lithography, gravure, flexography, letterpress, and screen printing (US EPA, 1990a). A typical printing process includes the following steps: image processing, platemaking, printing, and finishing. Characteristics of image processing and finishing are similar for all the printing processes. Platemaking and printing characteristics depend on the type of printing process as summarized in Table 3-14. Each step and associated wastewater discharges are discussed herein.

Table 3-14. Printing Process Characteristics

Printing Process	Products	Plate Material	Printing Inks	Wastewater Discharges
Lithography	Books, brochures, flyers, periodicals	Aluminum or aluminum/ copper alloy	Petroleum or soy based	Isopropyl alcohol (from fountain solutions), cleaning solutions, trace amounts of ink, organic
Gravure	Magazines, catalogs	Copper plated steel	Solvent based	Metals (from platemaking)
Flexography	Packaging, labels	Acrylate polymer	Water based	Organic plate materials, inks
Letterpress	Books, stationery, business cards	Zinc, magnesium or copper	Solvent based	Metals (from platemaking), trace amounts of solvent
Screen Printing	T-shirts, posters, wallpapers	Organic emulsions	Solvent based	Trace amounts of solvent

Most programs for commercial printers focus on lithographic printers as they tend to predominate in most communities. Flexographic printers, while less common, are likely to have larger volume waste streams with higher metal content than lithographers. Flexography is an aqueous process using waterborne inks and should be considered as a potential source of metals in wastewater.

3.5.2.1 Best Management Practices

Pollution prevention programs based on BMPs have been developed for printers in several other areas. BMPs for printers tend to focus on reducing air pollutant emissions (primarily from volatile organic compounds [VOCs]), the generation of VOC-containing wastes and silver-bearing wastewater. Approaches to reducing VOCs often entail replacing solvents with aqueous materials that may impact the quality of wastewater.

Many BMP documents are available for printers. The BMPs listed below are typical and based on BMPs recommended by the City and County of San Francisco (CCSF, no date, Clean Image...) and Union Sanitary District (USD, 1993).

Photographic wastes. Silver is the primary pollutant of concern for wastewater. Typically, BMPs suggest (or agencies require) that silver-containing wastes are treated or collected by a certified waste hauling service.

Prepress (proofmaking and platemaking). The wastewater generated by these processes might contain significant levels of metals. Where this issue is addressed, documents typically note that metal-containing wastewater must be collected for disposal by a contract service rather than being discharged to the sewer.

Inks. Most documents indicate that petroleum-based inks should be replaced by soy-based inks whenever possible to reduce VOC emissions. Water-based inks are also recommended for this reason. Often, procedures are recommended to minimize waste generation from maintenance of ink delivery systems. These procedures include cleaning ink fountains only when changing colors, recovering and recycling used ink, and preventing inks from drying up or forming skins. Most documents highlight the air pollution issues associated with ink solvents rather than wastewater issues related to ink metal content.

Fountain solutions. Generally, it is recommended that fountain solutions containing little or no isopropanol (IPA) should be used to replace fountain solutions with standard levels of IPA to reduce air pollutant emissions. In addition, some fountain solutions have been found to be high in chromium (Greenwood, 1996). Chromium-free solutions are available and are recommended.

Press cleanup. Dry cleanup methods, such as using rags that are picked up for laundering and reuse, are usually recommended in preference to wet methods, which can be sources of air pollutant emissions (i.e., solvents) or wastewater pollutant discharges. Agencies usually recommend that liquid waste generated during cleanup be collected and disposed of by a contract waste disposal service.

3.5.2.2 Program Elements

Programs for printers are based on the BMPs listed above. Many agencies permit printers or encourage them to become zero dischargers. Printing industry trade organizations and suppliers may be helpful in developing the programs for printers. The printing industry and its suppliers are already aware that their discharges may have environmental impacts. Printing Industries of Northern California (PINC) has worked with several agencies in the San Francisco Bay Area to conduct workshops and inform local printers of regulatory requirements.

3M Corporation, for example, has developed materials and processes that are aqueous rather than solvent-borne for the printing industry. In addition, they have evaluated their materials and processes with respect to metals loadings in wastewater and make fact sheets covering this information available on request (LWA, 1996a).

Many of the programs and outreach materials for printers focus on reducing VOC emissions. However, CCSF, USD, EBMUD, and the IWRC are some examples of agencies that have addressed wastewater issues, as well. Program information and materials collected for printers by the project team are listed in Table 3-15.

3.5.3 Dentists

Dental activities have been associated with the discharge of mercury and silver to the sanitary sewer. Dental amalgam contains mercury and routinely enters the sanitary sewer as a result of dental work. Chair-side traps collect a major portion of the amalgam evaluated from a patient's mouth during restoration or placement of a filling. X-ray activities at dental offices generate silver that may be discharged to the sanitary sewer. Programs to control silver discharges are the same as those discussed in the photoprocessors section and are discussed there.

Table 3-15. Information Collected for Commercial Printers

Program	Materials Reviewed	State	Region
Massachusetts Office of Technical Assessment	Program information	MA	1
Narragansett Bay Commission	Program information	RI	1
Alexandria Sanitary Authority	Program information	VA	3
Management Instit. for Environment and Business	Program information	VA	3
City of Raleigh	Program information	NC	4
Dade County	Brochures, program information	FL	4
Wisconsin DNR	Workshop, program information	WI	5
Western Lake Superior Sanitary District	Report, program information	MN	5
City of Albuquerque	Program information, fact sheet	NM	6
Iowa Waste Reduction Center	Guide book	IA	7
Montana PPP	Program information	MT	8
City of Boulder	Program information	CO	8
City of Phoenix	Program information, fact sheet	AZ	9
City of Tempe	Program information	AZ	9
Alameda County	Workshops	CA	9
Printing Industries of Northern California	Workshops, guidebook	CA	9
Union Sanitary District	Brochure, program information	CA	9
Sacramento RCSD	Program information, video	CA	9
City & County of San Francisco	Brochures	CA	9
Palo Alto RWQCP	Source ID report	CA	9
CCCSD	Program information	CA	9
City of Hayward	Program information	CA	9
City of Los Angeles	Source ID report	CA	9
California DTSC	Waste audit, guide book	CA	9
San Jose/ Santa Clara WPCP	BMPs, brochures, source ID report	CA	9
King County	Program information	WA	10
USEPA	Guide book		

The City and County of San Francisco and Western Lake Superior Sanitary District have conducted monitoring studies evaluating mercury discharges from dentists. Based on monitoring results for effluent from nine San Francisco dental buildings in 1992, it was estimated that dentists contributed approximately 12% of the mercury loading in San Francisco's treatment plant influent (CCSF, 1993a). Western Lake Superior Sanitary District monitored discharges from a major dental building in Duluth, MN. Mercury loadings from dentists in this building were estimated to be 0.3 g per dentist per day (Tuominem, 1996).

3.5.3.1 Best Management Practices

BMPs for silver-containing wastes are the same as those recommended under the section entitled Photoprocessors in this report. BMPs for mercury-containing wastes revolve around recycling amalgam traps and treating wastewater containing amalgam particles. BMPs for handling of dental amalgam are listed below and based on practices recommended by Western Lake Superior Sanitary District and King County (WLSSD, 1996). WLSSD and King County produced these BMPs in 1996 after working with the dental community to revise versions of dental facility BMPS produced earlier (WLSSD, 1996; Foster, 1996).

Recycling amalgam traps. Waste amalgam should not be disposed of in the garbage or down a drain. Traps are changed after flushing the line overnight to disinfect the trap. Gloves, gasses, and masks should be used when handling the trap. The trap is stored in a plastic covered container labeled 'Amalgam for Recycling." Amalgam can be mailed to a recycler if proper shipping guidelines are followed. Local waste handlers are also equipped to provide the service of collecting the amalgam and shipping to a recycler.

Amalgam wastewater. Wastewater might still contain high levels of mercury even after passing through the chairside trap. Treatment systems are available to reduce mercury levels further. Treatment of the wastewater is not yet required in any of the municipalities working with dentists. Implementing wastewater treatment is being explored with equipment manufacturers and dental associations.

3.5.3.2 Program Elements

CCSF, King County Hazardous Waste Management Program, and Western Lake Superior Sanitary District (WLSSD) have all worked with dentists to address mercury discharges from amalgam waste. Programs emphasizing education and voluntary compliance have been found to be more effective with dentists than to implement a regulatory program. Programs have been developed through cooperative efforts with dental associations, equipment suppliers, and individual dentists. Guidance materials and BMPs are in the process of being revised in all three communities based on recent coordination efforts with dentists.

WLSSD initiated a Mercury Zero Discharge Project in 1995 with the goal of using pollution prevention strategies to control sources and determine which strategies are most effective (Tuominen, 1996). A targeted initiative for dental offices is part of the program, including outreach to dentists and development of mercury recycling/disposal procedures. WLSSD developed BMPs for dental offices by working with the local dental society. They have also worked with local dentists to evaluate and promote methods for collecting and removing amalgam from the wastewater stream. An important element of this program is the cooperative effort between the dentists and the sanitary district. Wastewater discharges from monitored dental facilities showed a 69% reduction in mercury loadings when 1996 levels (end of first year of Zero Discharge Project) were compared to 1992 levels.

The City of Albuquerque has developed BMPs for dentists and conducted a survey of dentists to evaluate mercury and silver disposal practices (Hogrefe, 1996). As part of this survey, it was estimated that only 13% of the dentists recycle the amalgam collected in traps. Albuquerque is conducting outreach to encourage dentists to recycle amalgam. In the Washington, D.C., area, the local dental societies have entered into a voluntary agreement with the Department of Public Works to educate its members regarding proper handling of amalgam wastes (DCDPW, 1995).

Other communities with concerns regarding mercury in wastewater have also developed programs and materials targeting dental facilities. Program information and materials collected for dental facilities by the project team are listed in Table 3-16.

3.5.4 Photoprocessors

Photoprocessing businesses conduct photographic or x-ray processes. Included are printers, medical and dental facilities, photofinishers, veterinary facilities, and laboratories. Silver is the primary pollutant of concern associated with photoprocessing and is typically of concern with respect to wastewater pollution. It is found in spent fixer solutions used in the developing process and wash water. Selenium is found in photographic toners and might present concerns in some communities with respect to wastewater discharges.

Table 3-16. **Information Collected for Dental Facilities**

Program	Materials Reviewed	State	Region
Norfolk Naval Dental Clinic	Source ID report	VA	3
City of Raleigh	Program information	NC	4
District of Columbia DPW	Program information	DC	3
Dade County	Program information	FL	4
Western Lake Superior Sanitary District	Program information, brochure, source ID report	MN	5
Greater Milwaukee TMTF	Source ID report	WI	5
Indiana Dept. of Environmental Management	Program information	IN	5
City of Albuquerque	Program information, BMPs, fact sheet, survey	NM	6
City of Phoenix	Source ID report	AZ	9
City & County of San Francisco	Source ID report, program information	CA	9
Sacramento RCSD	Program information, source ID report	CA	9
City of Los Angeles	Source ID report	CA	9
Valley Sanitary District	Program information	CA	9
Seattle Metro, King County	Program information, poster, guide book, Source ID report	WA	10

3.5.4.1 Best Management Practices

BMPs revolve around not discharging silver-containing or selenium-containing wastes to the sewer. The BMPs listed below are based on BMPs recommended by Sacramento Regional County Sanitation District (SRCSD, 1994), City of Albuquerque, and Palo Alto RWQCP (PARWQCP, 1995).

Silver-containing wastes. Spent fixer solutions cannot be discharged to the sewer. It must either be treated onsite with a silver recovery unit or collected by certified silver recycler. Most businesses choose to have the solutions hauled off-site. More dilute solutions like wash water are often allowed to be discharged to the sewer. Larger facilities with larger wastewater volumes would be expected to treat their washwater.

Selenium-containing wastes. Toners containing selenium should not be discharged to the sanitary sewer.

3.5.4.2 Program Elements

Programs developed for photoprocessors prohibit discharge of silver containing solutions to the sanitary sewer. Requirements of having silver wastes hauled off-site or treated prior to discharge are often enforced through ordinances and permit programs. Outreach to educate photoprocessors concerning these requirements is conducted through brochures and workshops.

The Silver Coalition has developed a Code of Management Practice for silver discharges that provides guidance on treatment alternatives, sample permit language and BMPs (Silver Coalition, 1995). Their recommendations have been implemented in several municipalities around the country, the City of Albuquerque among them.

As part of its silver program, the City of Albuquerque has developed a recognition program (Hogrefe, 1996). The program is called the 5 ppm Silver Program and was developed jointly with the New Mexico Silver Users Association. Businesses are presented with a certificate that recognizes accomplishment with respect to reducing silver bearing liquid wastes and meeting wastewater discharge limits of 5 ppm for silver.

Program information and materials collected by the project team for photoprocessors are listed in Table 3-17.

3.5.5 Jewelry Manufacturing

Jewelry manufacturing has been identified as a source of cyanide, silver, and other metals in wastewater. Some communities have addressed this as a significant source of these pollutants. The City of Albuquerque, New Mexico conducted a survey in 1995 that identified 163 businesses involved in jewelry manufacture in their service area (Hogrefe, 1996). Of these businesses, approximately 90% were considered small or medium businesses based on the number of employees and volume of metals processed. The City is working with jewelers to reduce silver discharges and address other pollutants associated with jewelers.

Table 3-17. Information Collected for Photoprocessors

Program	Materials Reviewed	State	Region
Narragansett Bay Commission	Program information	RI	1
Massachusetts Office of Technical Assessment	Program information	MA	1
Alexandria Sanitary Authority	Fact sheet, program information	VA	3
Lee County	Fact sheet, program description	FL	4
Dade County	Brochures, program description	FL	4
City of Albuquerque	Brochures, program information	NM	6
City of Boulder	Program information	CO	8
Sacramento RCSD	Program information, fact sheet	CA	9
City & County of San Francisco	Brochure, program information	CA	9
Palo Alto RWQCP	Program information, brochures,	CA	9
EBMUD	Program information	CA	9
City of Livermore	Guide book, program description	CA	9
City of Los Angeles	Source ID report	CA	9
San Jose/ Santa Clara WPCP	Program information	CA	9
Valley Sanitary District	Program information	CA	9
King County	Program information	WA	10
US EPA	Guide book		
WEF P2 Committee	Guide book		
Silver Coalition/AMSA	Code of Management Practice		

Activities conducted during jewelry manufacture that generate metals or cyanide-containing wastes are divided into the categories of casting, stripping, and finishing. Casting activities include wax mold production, dewaxing, devestment, and casting. Stripping activities include acid pickling and cyanide bombing to remove metal oxides and casting residues. Finishing activities include deburring, polishing, and electroplating. The specific processes most likely to generate wastewater pollutants are devestment, stripping and deburring (Southside Water Reclamation Plant, 1994).

3.5.5.1 Best Management Practices

The following BMPs are used by the City of Albuquerque for jewelry manufacturers (Southside Water Reclamation Plant, 1994):

Casting and Devestment Operations. Casting involves melting metal and pouring it into a mold to make the metal piece. While no liquid wastes are generated by this process, the use of deoxidizing casting alloys might reduce the need for stripping processes later. Devestment removes the casted piece from the mold and can be done by a wet process or a dry process. The wet process generates wet waste that is nonhazardous but its solids content could plug sewer lines. In addition, this wet waste might not be accepted by municipal waste haulers. The dry process is recommended because the dry wastes may be disposed of as solid waste.

Stripping Operations. Pickling uses strongly acidic solutions to remove oxidized metals. Waste pickling solutions contain high levels of metals. It is recommended that metals be recovered from the solution and the acid solution reused. Pickling solution should not be discharged to the sewer. Cyanide bombing is another stripping process that not only generates cyanide-containing wastewater but is also dangerous because of the potential worker exposure to cyanide fumes. It is recommended that other stripping processes be used. Alternatives are pickling or a two-step process involving oxide removal with trisodium phosphate followed by ultrasonic cleaning.

Deburring and Finishing. Deburring and finishing operations generate wastewater streams containing particulate metals. The recommended practice is to install settling tanks to recover the metals and allow reuse of the water.

3.5.5.2 Program Elements

Based on the information collected by the project team, fewer programs target jewelry manufacture than some other commercial sources evaluated. Fewer communities have many businesses that fit this category, although some larger cities might have significant numbers of jewelry manufacturers, and certain areas of the country are known for distinctive jewelry (New Mexico, for example). The programs evaluated focus on encouraging jewelers to recover metals wherever possible and to avoid using cyanide bombing. Program elements include BMPs, guidance manuals, recognition programs, and financial incentives. In the City of Albuquerque, jewelry manufacturers are included in the 5 ppm Silver Program described in the photoprocessors section of this report. Program information and materials collected by the project team for jewelry manufacturers are listed in Table 3-18.

There is a distinct financial incentive for jewelers to recover metals from wastewater streams as this not only reduces waste disposal costs but the recovered metals can be sold. For example, a large jewelry manufacturer (125 employees) in Massachusetts invested approximately $95,000 in a metals recovery process (Massachusetts OTA, 1990). In the first year of operation, the system recovered 263 troy ounces of gold and 2,144 pounds of copper. Revenues from the sale of the gold and copper were $107,200 and $879, respectively. Traditional waste treatment processes would have recovered less gold (~$40,000) and required payment for copper sludge at a cost of $1,350.

Table 3-18. Information Collected for Jewelry Manufacturers

Program	Materials Reviewed	State	Region
Massachusetts Office of Technical Assessment	Program information, case study	MA	1
City of Albuquerque	Brochures, program information, guide book, recognition program, flyers	NM	6
City & County of San Francisco	Source ID report	CA	9
City of Los Angeles	Fact sheet	CA	9
California DTSC	Guide book	CA	9

3.5.6 Cooling Water Systems

Zinc, TBT, and copper are the primary pollutants associated with cooling water system releases. The sources of copper include heat exchangers, condensers, and piping. Wood slats are sometimes impregnated with copper to preserve the wood, and copper is an ingredient in additives used to control algae growth (PARWQCP, 1996; Montgomery Watson, 1995). Zinc originates from galvanized steel structures and is sometimes added in the form of zinc orthophosphate to control corrosion. Palo Alto RWQCP has identified facilities utilizing tributyltin for algae control and the City of Los Angeles is concerned with the use of hexavalent chromium as a corrosion control additive (PARWQCP, 1996a; City of Los Angeles, no date). In analysis of water released from 14 cooling towers in San Francisco, copper and zinc were detected in all samples while cadmium, chromium, lead, mercury, and nickel were detected in some samples (Montgomery Watson, 1995). These pollutants end up in the waste stream after periodic blowdown from cooling tower systems. Blowdown prevents the buildup of dissolved substances in the recirculated cooling water which results in decreased heat transfer efficiency. The wastewater is typically discharged to the sanitary sewer system, however there are still some systems connected to storm drains.

Buildings and industries with cooling water systems were surveyed as part of a San Francisco study (Montgomery Watson, 1995). Of the 133 cooling towers surveyed, 42% were associated with office buildings, 11% were associated with hotels/motels, 26% were associated with unknown uses, and the remaining 21 % were affiliated with apartment buildings, hospital/medical facilities, municipal buildings, universities, industry, and commercial facilities.

3.5.6.1 Best Management Practices

The common approach to prevent discharge of pollutants from cooling water systems is to prevent corrosion and recommend acceptable types of treatment additives. Typical BMPs for cooling water systems are summarized below and are based on those recommended by the Palo Alto RWQCP.

Maintenance. Regular cleaning with brushes, pressurized water, or steam can reduce the need for chemical additives. After the physical cleaning, the system should be treated with a prefilming agent to prevent corrosion. Avoid using any additives that contain copper, chromium, tributyltin, and zinc, and only add the chemicals while the system is off-line to avoid discharge of untested waters to the sewer system. When required, replace parts with components that do not contain copper or zinc.

Monitoring. Regularly test the cooling water to determine the concentrations of copper, iron, zinc, carbon dioxide; chorine, chlorobromine, or ozone (if added); pH; conductivity; and water velocity in the piping. The concentrations might indicate operational problems, as well as noncompliance with discharge standards. Measure corrosion with corrosion coupons, corrosion rate meters, or other monitoring devices.

Operation. Maximize the "cycles of concentration" to reduce water use and minimize chemical additive use. Install and maintain a good automated control system to prevent overfeeding or underfeeding of chemicals. Filtration of the blowdown might improve the quality of recirculated water and thus decrease corrosion in the system. Treatment with metal absorbing devices might be warranted before discharge to the sanitary sewer.

3.5.6.2 Program Elements

BMPs to control the quality of blowdown water have been developed by the Palo Alto RWQCP. Some of the other programs have made operational recommendations for cooling water systems, but these have been primarily geared towards reducing water usage. Palo Alto RWQCP arranged public meetings to receive input from cooling tower operators and treatment chemical suppliers to prepare BMPs and ordinance requirements. Within the ordinance, implementation of several BMPs was required, and a threshold level of 0.25 mg/L copper set for cooling water discharges. Use of treatment additives containing copper, chromium, and tributyltin were prohibited in the Palo Alto RWQCP's service area. In December, 1995, use and sale of tributyltin was banned in nine Bay Area counties by the Despartment of Pesticide Regulations (PARWQCP, 1996). Program information and materials collected for cooling water systems by the project team are listed in Table 3-19.

3.5.7 Machine Shops

For purposes of program review, the category, "machine shops," was designated to describe all businesses that work with fabricated metal products. These businesses produce parts or process materials through contracts with other companies or they might be part of a larger manufacturing facility, performing work only for that company. Pollutants at machine shops include oils, metals, solvents, and metal coatings generated through machining, surface treatment and plating operations, metal cleaning and stripping operations, and paint application (US EPA, 1990a). Pollutants enter the waste stream when spent process solutions, filter sludges, rinse waters, and used oil are disposed.

Table 3-19. Information Collected for Cooling Water Systems

Program	Materials Reviewed	State	Region
ConnTAP	Fact sheet	CT	1
Narragansett Bay Commission	Program information	RI	1
North Carolina Department of the Environment	Pollution prevention tips	NC	4
Minnesota Technical Assistance Program	Fact sheet	MN	8
Santa Clara County/ Southern San Mateo County	List of products and services	CA	9
City of San Jose Environmental Services	Guidebook for water conservation	CA	9
Palo Alto RWQCP	Booklet, BMPs, fact sheet	CA	9
City of Los Angeles	Fact sheet	CA	9
City and County of San Francisco	Survey and report	CA	9

The Palo Alto RWQCP determined that the two major sources of pollutant discharge from machine shops are wastewater from parts tumbling and deburring and mop water from shop cleanup (PARWQCP, 1995). Machine shops inspected in San Francisco were also found to have limited discharges to the sanitary sewer. The operators were aware of the hazardous nature of their materials and have been implementing the required BMPs (CCSF, 1996).

3.5.7.1 Best Management Practices

BMPs for machine shops involve good housekeeping, proper storage and handling of materials, waste minimization, and proper disposal practices. The basic principles of pollution prevention at machine shops are summarized based on BMPs developed by the Palo Alto RWQCP (PARWQCP, 1995) and City of Phoenix (City of Phoenix, 1996). However, since a more intricate knowledge of the operation is required before making recommendations in process control, publications, such as the pollution prevention guide produced by US EPA (1990a), are suggested for adequate background information.

Housekeeping. Install secondary containment around machinery and use absorbents to clean up any spills that occur. Use dry cleanup whenever possible to minimize the volume of wash water generated.

Waste Minimization. Reuse, reclaim, or recycle cleaning fluids or rinse waters whenever possible.

Storage and Handling. Store materials indoors or under cover, place materials on pallets or off the ground, check frequently for leaks or corrosive activity, and properly label all containers. Secondary containment might be required for storage areas. Store and handle hazardous wastes in special hazardous waste containers or in drums with secondary containment.

Disposal. Test wastewater before discharge to the sanitary sewer to ensure compliance with local requirements. Pretreatment might help achieve the acceptable concentrations. Dispose through a legally licensed service all wastes generated by the operation that fit the legal definition of hazardous waste.

3.5.7.2 Program Elements

Many communities have issued BMPs for machine shops. Compliance with the BMPs is enforced through the local wastewater authority since disposal of wastewater generated is usually to the sanitary sewer system. BMPs determined to be critical have been added to sewer use ordinances in some areas. Unless materials are stored or handled outside, there are usually no risks to the storm drain system. Program information and materials collected for machine shops by the project team are listed in Table 3-20.

3.5.8 Dry Cleaners

Dry cleaning businesses are located in most cities. However, the actual dry cleaning might not take place at the business location. Businesses conducting dry cleaning on site are typically subject to hazardous waste and air program requirements in addition to regulation by a wastewater authority. Dry cleaning activities are primarily associated with perchloroethylene discharges to the sanitary sewer (Harader, 1994). Perchloroethylene is the solvent used in dry cleaning processes that cleans the clothes. Most of this solvent is recovered, and impurities, including water, soils, and body oils, are removed so that the perchloroethylene can be re-used. The water separator that removes impurities from the perchloroethylene is one source of concern to wastewater. Perchloroethylene's physical properties allow it to penetrate very small cracks giving it the potential to "leak" from sewers. It also passes through soil quickly, which can contaminate groundwater.

Many dry cleaners also have laundry facilities. Laundry graywater is a source of metals in wastewater. Pollution prevention strategies pertaining to laundry are discussed in Chapter 4.0. Dry cleaning activities are discussed in this section.

One recently-introduced alternative to dry cleaning is a computer-controlled wet cleaning process. Water temperature, heat, and agitation are carefully controlled to prevent damaging clothes. UCLA's Pollution Prevention Education and Research Center has been evaluating one shop using this process since early 1996 (San Jose Mercury News, 1996).

Table 3-20. Information Collected for Machine Shops

Program	Materials Reviewed	State	Region
US EPA	Pollution prevention guidebook		
Narragansett Bay Commission	Program information	RI	1
Lee County Division of Natural Resources Management	Guidebook	FL	4
Research Triangle Institute	Guidebook	NC	4
Rouge River Program Office	Program information	MI	5
Iowa Waste Reduction Center	Program information	IA	7
City of Phoenix	BMPs	AZ	9
Palo Alto RWQCP	BMPs, guide book, program information	CA	9
Novato Sanitary District	Source identification	CA	9
City of San Jose	Source identification	CA	9
Union Sanitary District	Program information	CA	9
Santa Clara County Pollution Prevention Program	Program information	CA	9
City of Livermore	BMPs	CA	9
Ventura County	BMPs	CA	9
Sacramento Regional County Sanitation District	Program information	CA	9
De Anza College	Workshop	CA	9
Metro	BMPs	WA	10

3.5.8.1 Best Management Practices

BMPs for dry cleaners revolve around preventing perchlorethylene from entering the sanitary sewer. Three waste streams have been identified as significant sources of perchlorethylene to wastewater: water-separator discharge, spills to floor drains, disposal of still bottoms. BMPs addressing these sources are listed below and are based on those used by the Sacramento Regional County Sanitation District (SRCSD, 1994).

Separator Water and Still Bottoms. Discharge of separator water and still bottoms to the sanitary sewer is prohibited. Instead, these wastes are collected in separate containers and disposed as hazardous waste by a certified waste hauler.

Spill Containment and Response. Dry cleaners must provide spill containment for machines containing solvents. The containment area should be impermeable, capable of holding 110% of the largest possible spill, should prevent the spill from reaching the sanitary sewer, storm drains, or soil. Spills should be cleaned up with rags that can then be run through dry cleaning equipment to recover the solvent.

Equipment. Closed-loop dry cleaning machines are available that produce a fraction of the waste that "vented" machines do. Closed-loop machines may generate less than one gallon of wastewater per month compared to 100 gallons per month for "vented" machines. Other equipment than can help minimize wastes are refrigerated condensers and cooling towers.

Operating Practices. Recommendations include not adding excess water or damp clothes to dry cleaning machine, tracking water usage to detect possible leaks in cooling equipment, and maintaining and steam stripping equipment regularly.

3.5.8.2 Program Elements

Programs for dry cleaners often include permits. Outreach is conducted describing BMPs and regulatory requirements through brochures and workshops. Program information and materials collected for drycleaners by the project team are listed in Table 3-21.

Table 3-21. Information Collected for Drycleaners

Program	Materials Reviewed	State	Region
Narragansett Bay Commission	Program information	RI	1
Washington Suburban Sanitary Commission	Program information	MD	3
Alexandria Sanitary Authority	Program information	VA	3
Dade County	Brochures, program information	FL	4
Bureau of Solid and Hazardous Waste Management	Program information	FL	4
Montana PPP	Program information	MT	8
City of Boulder	Program information	CO	8
Sacramento RCSD	Program information, brochure, technical report, BMPs	CA	9
Palo Alto RWQCP	Source ID report	CA	9
Union Sanitary District	Program information, brochures	CA	9
Santa Clara County Pollution Prevention Program	Program information	CA	9
EBMUD	Program information	CA	9
San Jose/ Santa Clara WPCP	Source ID report	CA	9
Orange County	Program information	CA	9
King County	Program information	WA	10
US General Accounting Office	Report		
US EPA	Guide book		
WERF	Guidance manual		

3.5.9 Ceramics

Glazes and clays used in pottery studios can be sources of wastewater pollution. Colored glazes typically contain metals, such as chromium, nickel, cobalt, copper, manganese, and iron (PARWQCP, 1995). Clays, while not associated with aquatic toxicity, can clog sewer lines if discharged in large amounts. Depending on the number of commercial ceramic studios in a community, this might not be a large source of wastewater pollution. However, communities with serious metal water quality problems might want to evaluate this source.

3.5.9.1 Best Management Practices

The Palo Alto RWQCP has developed the following recommendations for ceramic studios (PARWQCP, 1995):

Glazes. Glazes should never enter the sewer. If possible use a separate working area for glazes and for clays. Store glazes in covered containers away from sinks. Use secured shelves with lips or doors to help contain spills should they occur. Clean up glazing materials with a two-bucket sequential rinse rather than rinsing in the sink. When the initial rinse bucket contains too many solids, place it where the water will evaporate. Mix glaze wastes and rinse water with clay, fire and dispose of as trash.

Clays. Working water containing clay should be collected in a bucket and the clay should be allowed to settle out. Equipment should also be rinsed in this bucket before rinsing in the sink. Mop floors and pour mop water into collection bucket. Once the clay has settled out, water from the collection bucket may be poured in the sink. The clay may be reused or mixed with waste glazes, fired and disposed of as trash.

Housekeeping. Seal floor drains to contain spills. Install small settling buckets in each utility sink and put sediment traps in drain pipes. Minimize water use at each stage of the pottery process.

3.5.9.2 Program Elements

Because ceramic studios are not likely to be major sources of pollutants, programs are voluntary and consist primarily of educational outreach. Program information and materials collected for ceramics studios by the project team are listed in Table 3-22.

Table 3-22. Information Collected for Ceramics Studios

Program	Materials Reviewed	State	Region
Western Lake Superior Sanitary District	Program information	MN	5
Palo Alto RWQCP	BMPs, program information, brochure	CA	9
California Department of Toxic Substances Control	Fact sheet	CA	9

3.5.10 Wood Finishers

Wood finishing and furniture making activities are associated with the generation of wastes containing solvents, volatile organic compounds (VOCs), and some metals. In general, releases to air are the focus of pollution prevention programs for wood finishers. However, some processes that might present concerns in wastewater are the use of waterborne coatings (a suggested alternative to solvent-borne coatings), caustic stripping, and the use of methylene chloride (EBMUD, 1996).

3.5.10.1 Best Management Practices

The following BMPs for wood finishers are based on those recommended by EBMUD.

Stripping. Cleanup residues from methylene chloride stripping using a dry process, such as rags, before rinsing with water. Rinsewater generated from caustic stripping should be screened to remove paint skins prior to discharging to the sanitary sewer.

Housekeeping. Prevent spills and accidental discharges from entering the sanitary sewer by installing physical barriers or sealing floor drains. Soiled rags should be disposed of as hazardous waste or cleaned by an industrial laundry.

3.5.10.2 Program Elements

The pollution prevention program for wood finishers developed by EBMUD included permits and outreach through brochures and workshops to explain program requirements. Program information and materials collected for wood finishers by the project team are listed in Table 3-23.

Table 3-23. Information Collected for Wood Finishers

Program	Materials Reviewed	State	Region
Management Institute for Environment and Business	Source ID report	VA	3
Montana Pollution Prevention Program	Program information	MT	8
Sacramento County	Program information, guide book, video	CA	9
East Bay Municipal Utility District	Program information, workshop, BMPs	CA	9

CHAPTER 4.0

RESIDENTIAL SOURCES OF POLLUTANTS

Residential sources have been associated with wastewater and stormwater pollution, and in some cases, contribute more pollutants than industrial or commercial sources. This chapter presents approaches used to address residential sources of pollution and information regarding specific sources of wastewater and stormwater pollution.

4.1 Approaches to Residential Sources

Residential source control strategies can be divided into three categories, which are described in the sections that follow:

- Public education;
- Technology-based strategies; and
- Legislative strategies.

4.1.1 Public Education

Because a regulatory and enforcement approach is often not applicable in the residential sector, source reduction can best be accomplished through educating the public and attempting to change habits by raising awareness. Consequently, public education is the most commonly applied source control strategy for the residential sector. For the public education approach to be effective, the communicated information must be clear, concise, and targeted at the appropriate audiences. Methods of disseminating information include brochures, point-of-purchase displays, media advertising, school programs, event exhibits, and outreach to businesses serving the public. Public education is discussed further in Chapter 5.0.

4.1.2 Technology-Based Strategies

Technology-based strategies typically involve a process modification or the use of certain equipment to achieve discharge reductions. For example, changing a supply water treatment process by adding corrosion inhibitors might reduce metals loadings due to household plumbing corrosion, while installing household graywater systems would address loadings contributed by laundry graywater. The effectiveness of these strategies depends on how well the technology targets a particular problem, as well as on the level of cooperation and participation. For example, from a technical standpoint, graywater systems would effectively eliminate the discharge of graywater to the sanitary sewer. However, implementation of this strategy would require major, widespread changes in the practices of builders, developers, landscapers, and homeowners. Implementation of corrosion control, on the other hand, only requires the participation of a relatively small group (water purveyors) and, therefore, implementation would be more straightforward.

4.1.3 Legislative Strategies

Legislative strategies involve implementing new local ordinances or changing regional or State laws. These approaches include product bans through local ordinances, product bans through regional or statewide legislation, or changes in plumbing codes. The effectiveness of this type of strategy depends largely on the ability to enforce the ordinance or law and the ease or difficulty with which such a restriction can be circumvented.

One example of an effective legislative strategy has been the mercury ban in latex paints implemented nationwide in 1990. Prior to the ban, mercury was added to paint to improve mildew resistance, and mercury levels in paints were typically on the order of 125 parts per million (ppm) (CCSF, 1994). While the ban has only applied to indoor latex paints, a recent analysis of both exterior and interior paints shows the average mercury level to be 0.26 ppm and the maximum level to be 2 9 ppm. In addition, after-market additives that can be used for mildew resistance are also unlikely to contain mercury, even though the Federal mercury restriction does not apply to these products. Essentially, the mercury ban created an anticipation among manufacturers that mercury was an ingredient of concern, and was, therefore, likely to be banned in related products at some future time if the producers themselves did not act voluntarily.

4.2 Specific Residential Sources of Pollutants

Residential sources of wastewater pollution include corrosion, indoor pest control, pet care, household cleaners, and laundry graywater. Residential sources of stormwater pollution include landscape maintenance, vehicle maintenance, pool and spa discharges, and painting activities. Associated pollutants, studies, and strategies addressing each of these sources are discussed in the following subsections. Information for landscape maintenance, indoor pest control, and pet care is presented under one heading, Pesticide Use and Landscape Maintenance. Pollutants typically associated with each of these activities based on information collected for this report are listed in Table 4-1.

4.2.1 Household Plumbing Corrosion

CCCSD estimated that household plumbing corrosion accounted for about 9% of the CCCSD residential copper loadings and 4% of the CCCSD residential lead loadings. Other communities have estimated corrosion contributions to copper loadings to be much higher, ranging from 40% to 75% of total copper influent loadings (PARWQCP, 1996; NSD, 1996; Save The Bay, 1996). Factors influencing household plumbing corrosion contributions to metals loadings include water supply corrosivities, housing age distributions, and corrosion control practices.

Table 4-1. Pollutants Associated with Residential Activities

Residential Source	Concern to Wastewater or Stormwater	Associated Pollutants
Corrosion	Wastewater	Cu, Pb, Zn
Laundry graywater	Wastewater	heavy metals
Indoor pest control	Wastewater	pesticides
Pet care	Wastewater, Stormwater	pesticides (flea dips), animal wastes
Landscape maintenance	Stormwater	pesticides, nutrients
Vehicle maintenance	Stormwater	oil, heavy metals
Painting activities	Stormwater	heavy metals, solvent
Household cleaners	Wastewater	solvents, ammonia, bleaches
Pools and spas	Stormwater, Wastewater	chlorine, copper
Root control products	Wastewater	copper

Household plumbing corrosion is typically reduced using technology based strategies directed at the water supply and plumbing materials. Examples in Palo Alto and Novato, California are described.

A study conducted by Palo Alto RWQCP (PARWQCP, 1996) investigated copper piping corrosion and potential corrosion reduction measures. The study included the following elements: estimation of corrosion rates in copper piping; evaluation of corrosion in heating systems, cooling systems, and hot water recirculating systems; and the effect of addition of chemical corrosion inhibitors to the distribution system. Based on the results of this study, Palo Alto RWQCP is planning to implement the following measures: consider implementing the corrosion inhibitor strategy recommended by the study (i.e., add orthophosphate to the water supply at 1 mg/L), develop plumbing BMPs in cooperation with the Cities of Sunnyvale and San Jose, and develop educational materials to encourage the use of non-copper plumbing materials.

Novato Sanitary District (NSD) worked with its water purveyor, Sonoma County Water Agency (SCWA), to reduce copper loadings from corrosion by instituting pH control. NSD was experiencing difficulty meeting its NPDES effluent copper limits. Source identification studies indicated that approximately 75% of the copper loadings in NSD's plant influent could be attributed to household plumbing corrosion. Adjustment of the water supply pH has resulted in dramatic reduction in copper effluent loadings as discussed further in Chapter 6.0.

Corrosion of household plumbing has been evaluated as a source of copper and lead by several agencies and organizations including:

Massachusetts Office of Technology Assessment (OTA)
Save The Bay, RI
New Jersey Environmental Federation
Dade County Department of Environmental Management, FL
US EPA Region 5
City of Phoenix, AZ
City of Tempe, AZ
Central Contra Costa Sanitary District, CA
Palo Alto RWQCP, CA
Novato Sanitary District, CA
King County Water Pollution Control Division, WA

4.2.2 Laundry Graywater

A study conducted by Central Contra Costa Sanitary District (CCCSD) identified laundry graywater as a significant source of heavy metals, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc (LWA,1994a). For most of the parameters examined, color laundry loads were shown to contain significantly higher levels of metals than did white loads. This might be attributable to leaching of textile dyes and/or to the fact that color clothes are more often outer clothes which tend to collect more dirt and to have more metal fixtures (i.e., snaps, zippers, etc.) attached to them. In addition to metals loadings attributable to the laundry itself, detergents and other laundry products can contribute significant amounts of arsenic, cadmium, and chromium to laundry graywater. Laundry graywater has also been evaluated as a possible source of chloroform from the use of chlorine bleach (Corsi, 1994).

Public education, technology-based strategies, and legislative strategies can all address laundry graywater as a source of residential metals. Public education would focus on an effort to modify residential laundry practices. Technology-based strategies include the use of graywater systems and reducing the use of metals-containing clothing dyes. Legislative strategies would involve passing a local ordinance requiring developers to install graywater systems in a certain percentage of new homes.

The washing of color loads in cold water rather than warm water could significantly reduce metals in graywater by reducing the amount of dye leaching from clothes during washing. (Energy conservation would be a secondary benefit of this option.)

The use of alternative, metal-free dyes would also help reduce residential metals loadings from laundry graywater. This would require a study to determine that dyes are indeed a significant source of residential metals. If this hypothesis is proved, a cooperative effort with dye manufacturers to develop and use acceptable alternatives (less toxic, metal-free dyes) would be in order. Such an effort may be beyond the capabilities of one municipality, and it would be more effective to refer this study to the state or US EPA for administrative and financial support.

Residential activities also impact loadings in commercial laundries. A source identification effort by a diaper service identified diaper rash ointment as a source of zinc in its laundry graywater (Massachusetts OTA, 1992). Outreach to its customers reduced zinc levels in the diaper service's wastewater.

4.2.2.1 Graywater Systems

Another technology-based idea that may be effective in reducing wastewater loadings from graywater is an on-site residential graywater system that can be used to collect graywater and recycle it to a subsurface drip irrigation system that can be used to water lawns, trees and shrubs. Graywater systems address all pollutants present in laundry wash water including those from dirt, clothing dyes and detergents. The potential to reduce metals entering the residential sewer wastewater through application of residential graywater systems complements water conservation as a justification for the use of such systems. To ensure that minimum standards for health and safety are met by residential graywater systems, graywater standards were added to the California State Plumbing Code in 1994 (California Department of Water Resources, 1994). Recent estimates indicate that it would cost the homeowner approximately $1,500-$3,000 to set up a typical graywater system, including piping and perforated tubes for the irrigation system (Sacramento Bee, 1994).

The graywater standards were adopted to allow systems to be installed in single family dwellings and were designed to provide consistent standards that meet minimum health and safety requirements. In addition, they were developed to provide relief for residential landscapes during water shortages and to enable the development of business and economic opportunities. Graywater systems have the advantage of addressing both water conservation and pollution prevention issues. In addition, the systems appear to be straightforward to install and maintain. However, to substantially reduce wastewater loadings, widespread use of graywater systems within a community would be necessary. This would require a substantial outreach effort.

Promoting graywater systems for larger sources, such as apartment buildings, laundromats, schools, and hotels might address wastewater loadings more effectively. The current graywater standards in California were developed for single family dwellings. However, a law was passed in 1995 to revise the graywater standards to allow for use by multiple family dwellings, commercial businesses, and other larger sources. These standards went into effect in January, 1997 (Prillwitz, 1995).

Agencies providing information on laundry graywater as a residential source of pollutants include:

Central Contra Costa Sanitary District, CA
Palo Alto RWQCP, CA
Eastern Municipal Water District, CA
City of Tempe, AZ
Seattle/ King County, WA

4.2.3 Pesticide Use and Landscape Maintenance

Pesticides are used by homeowners for landscape maintenance, indoor pest control, and pet care. Control strategies targeting general pesticide use and programs specifically targeting organophosphate pesticides are discussed in the following subsections. In addition, landscape maintenance can contribute nutrients and other pollutants. Programs addressing fertilizer use, water conservation, and native plant selection, in addition to pesticide use, are also described.

4.2.3.1 General Pesticide Use

With regard to pesticide usage habits, surveys conducted in Virginia, Maryland, and Minnesota indicate that about two-thirds of homeowners perform their own lawn care (Schueler, 1995). Approximately 20% to 40% of homeowners use insecticides, with the most common products used including diazinon and chlorpyrifos. The Maryland survey indicated that two-thirds of the homeowners who apply their own pesticides rinse their equipment over grass, pavement, or directly into gutters or storm sewers. One conclusion that can be drawn from these surveys is that a need exists for more public education regarding pesticide handling and disposal.

Strategies for controlling sources of pesticides include:

- Using integrated pest management (IPM) methods;
- Switching to less toxic pesticides, such as pyrethrins and insecticidal soaps, where appropriate and available; and
- Properly handling and disposing of pesticides to minimize the amount of pesticide entering the sewer or storm drain.

Integrated pest management is a program that is typically applied to agriculture, although its principles can also be applied to urban pest control (Robinson et al., 1995). IPM encourages the use of non-chemical controls, but allows for pesticide use under certain circumstances. The message of IPM is that alternatives to pesticides exist which can result in significant reductions in pesticide use. Many resources describe IPM practices and alternatives. One comprehensive resource is the Bio-Integral Resource Center and its 1996 Directory of Least-Toxic Pest Control Products (IPM Practitioner, 1995).

IPM is based on the implementation of four basic principles.

1. The pest causing the problem must be identified so that a pest control approach best suited to the particular pest can be chosen.

2. The applicator must decide what level of pest control is necessary. For example, a residential yard might not need to be completely free of insects and weeds.

3. Long-term strategies should be used to keep pests under control. Long-term strategies include introduction of disease-resistant plants, use of beneficial insects such as ladybugs, and removal of accessible food supplies for ants and cockroaches.

4. Short-term strategies are used when pests cannot be controlled due to unusual circumstances. Short-term strategies may include the use of pesticides, but the least toxic pesticide that will be effective is recommended.

Applying IPM to lawn care includes several practices (Schultz, 1990). Grass can be fertilized using organic fertilizers. IPM recommends fertilizing lightly and less frequently. Grass can be mowed higher leading to a healthier lawn that is more weed resistant, thus decreasing the need for pesticides. If pest problems occur, some damage should be tolerated and the least toxic controls available should be used. For example, biological controls, such as certain fungi or bacteria, can be effective pest controls. Also, the grass type chosen should be pest resistant and compatible with the local climate. Such practices can reduce the use of pesticides.

With respect to educating the public regarding these practices, Seattle METRO has developed a Green Gardening Program consisting of a multi-level education campaign encouraging pesticide use reduction and recycled materials use in urban landscaping. The program strives to educate people who currently use pesticides about easy, effective, and less toxic alternatives. Through public outreach, the program teaches people to look at their yards and gardens as a dynamic ecosystem and to curb all "preventative" calendar spraying. The program provides information on the dangers of pesticides and safest application techniques. Disposal of hazardous waste containers is also taught, but the emphasis is on preventing pest problems and choosing safer alternatives. In 1993, Seattle used four public education tools:

1. Workshops titled "Alternatives to Pesticides" were offered during the growing season at local nurseries.

2. A slide show called "Green Gardening" was presented to 23 community groups.

3. A "Green Gardening tour weekend" was held featuring 16 organic gardens open to the public.

4. Written brochures on alternative pest controls, pest and disease-resistant plants, and organic gardening were distributed at all Green Gardening events and at local nurseries.

In addition to these four tools, Seattle was also considering a program that would provide identifying signs for yards using Green Gardening techniques. The Green Gardening program also provides a consultant to train nursery workers on alternatives to pesticide use.

4.2.3.2 Public Education Programs for Organophosphate Pesticides

Sources of pesticides are likely to be unregulated commercial businesses or residential home and lawn maintenance. Public education programs have been implemented by several communities to encourage residents to implement the strategies discussed in previous sections. In particular, organophosphate pesticides, including diazinon and chlorpyrifos have been identified as pollutants of concern in both stormwater and wastewater around the country. Public education programs targeting diazinon or chlorpyrifos, as well as programs targeting pesticides in general, are described herein.

Diazinon was identified as the primary cause of wastewater whole effluent toxicity failures in several POTWs in US EPA Region 6 (Texas, Oklahoma, New Mexico) (Water, Environment & Technology, 1995). At the request of US EPA, CIBA Crop Production (diazinon manufacturer) conducted a study of 350 wastewater treatment plants in Texas, Oklahoma, and New Mexico, which are required to perform biomonitoring. The study results indicated that diazinon levels in effluent can be reduced through increased solids retention time and aeration capacity. However, public education efforts to discourage residents from pouring pesticides down the drain are more economical than treatment and have proven to be effective. A description of a public education program developed in response to toxicity failures in Oklahoma City, Oklahoma, follows. Greenville, Texas, also developed an effective public education program targeting diazinon which is described in more detail in Chapters 5.0 and 6.0.

Oklahoma City has a population of 480,000 and is served by four wastewater treatment plants with a total capacity of 81 Mgal/day (APA, 1995). Biomonitoring at all four plants identified toxicity which was linked to diazinon through toxicity reduction evaluations (TREs) conducted in 1992. Sources appeared to be residential; therefore, the City determined that a public education program represented the most economical and effective control strategy.

The initial task of the educational program was to conduct a series of user surveys. Separate surveys were conducted for the following groups: residential users; professional exterminators; lawn service and nursery professionals; veterinary clinics and groomers; animal shelters and kennels; janitorial services and carpet cleaners; apartments, motels, and hotels; food service establishments; and retail stores. The results of the surveys indicated that the public education program would be most effective by targeting residential users of pesticides. The City created its Public Education Program to inform the general public about the correct selection, handling, and disposal of pesticides. Program elements include brochures, bill inserts, public television programs, radio announcements, radio talk shows, information on buses and billboards, home and garden show exhibits, a home and garden club newsletter, and newspaper articles.

4.2.3.3 Landscape Maintenance

In addition to pesticides, landscape maintenance contributes other stormwater pollutants, including nutrients from residential fertilizer use and pet wastes. Programs have been developed to educate residents regarding landscaping activities and other residential activities generating pollutants. The Water Wise Gardener Program, Backyard Actions for a Cleaner Bay and Home*A*Syst are discussed below.

The Virginia Cooperative Extension has developed the Water Wise Gardener Program to encourage homeowners to implement best management practices that will reduce water pollution from fertilizers, pet wastes, erosion, and pesticide use (Aveni, 1996). Program goals that have been met include: 1) 85% of participants complete one year (1st and 2nd stages described below) of the Water Wise Gardener Program, and 2) documentation of a 40% reduction in nitrogen applied and a 25% reduction in yard wastes sent offsite, pesticides applied, and water used.

The Water Wise Gardener Program uses master gardeners to educate the public using a 5-stage process. The initial stage is to provide information to the public through seminars or workshops on topics including fertilization, IPM, plant selection, and composting. The second stage goes beyond the first stage of educating the public by encouraging individuals to participate at a deeper level of personal involvement. In the second step is the 'volunteer lawn' program in which homeowners sign an agreement whereby they volunteer to implement the recommended practices. A master gardener assists the volunteer in implementing at least 5 BMPs and to keep track of lawn and yard care activities. In the third stage, a volunteer lawn becomes a "demonstration lawn." After the homeowner has had a volunteer lawn for at least a year, they should be knowledgeable about how water quality relates to lawn care and their lawns should look well cared for. A yard sign is posted to highlight their efforts to the community. The fourth stage is training the homeowner to become a master gardener and thus expanding the program through this person's commitment to share knowledge with the community. The fifth stage is program evaluation which is conducted periodically to assess the program and determine future directions.

Backyard Actions for a Cleaner Chesapeake Bay is a public outreach program to: 1) inform citizens that their personal actions can impact the Bay; 2) provide hands-on information on gardening and lawn maintenance practices; and 3) show city dwellers and suburbanites how farmers are protecting the Bay (Leffler, 1996). Specific information was offered on wise fertilizer use, pesticide alternatives, and erosion control. The outreach strategy included video and radio public service announcements, and "Take It From Maryland Farmers" guides, posters, stickers, and displays. This 1995 outreach campaign resulted in the distribution of 5,000 guides and 3,500 calls to the Maryland Cooperative Extensions Home and Garden Information Center (advertised in the campaign).

Home*A*Syst is a national program that encourages homeowners to complete an assessment of pollution hazards in and around the home (Farm and Home Pollution Prevention Update, 1995). It is based on a program developed for farm assessments (Farm*A*Syst). These programs are intended to serve as a pollution risk assessment tool and a flexible implementation framework that builds interagency and private sector partnerships to support rural pollution prevention. A series of assessment worksheets identify pollution from a wide range of sources found on farms and in homes. Fact sheets and technical referrals are used to develop site-specific, voluntary action plans to prevent pollution.

Agencies and organizations providing materials and program information on landscape maintenance and pesticide use for the Source Control Assessment are listed in Table 4-2.

4.2.4 Vehicle Maintenance and Used Motor Oil

As discussed in Chapter 4.0, vehicle repair, maintenance, and washing generate pollutants, including heavy metals, oil and grease, and detergents that are discharged to the storm drain and the sanitary sewer. Residential vehicle maintenance has been addressed by pollution prevention programs and stormwater programs through public education efforts. These outreach efforts target used motor oil, residential vehicle maintenance, and residential car washing.

4.2.4.1 Used Motor Oil

Proper disposal of used motor oil has been targeted by many programs. Many communities have established household hazardous waste facilities where residents can dispose of hazardous wastes, including used motor oil. Many communities around the country provide household hazardous waste collection facilities and other means of collecting used motor oil. Some specific program aspects from the City and County of San Francisco (CCSF), Seattle/ King County, Ventura County, and Massachusetts OTA are described here as specific examples.

Massachusetts OTA established a recycling center to collect household hazardous wastes, including used motor oil, antifreeze, and photographic wastes as part of its Critical Parameters Project in Worcester, MA (US EPA, 1994). The recycling center received little use from business and moderate use from homeowners. It was felt that more publicity of the project would have increased the use of the recycling center. Even so, in the first year of operation, 1,400 gallons of waste were collected at the recycling center.

Service stations and auto repair shops sometimes accept used motor oil. The California Integrated Waste Management Board (CIWMB) encourages these activities through its used oil grants for local governments (CIWMB, 1994). Grants are provided to cities and other local governments to publicize used oil collection programs like the two described below. San Francisco and Ventura County have obtained these grants and used them to develop programs publicizing businesses that collect used motor oil. The City and County of San Francisco produced a map showing the 52 locations around the city that collect used motor oil. (CCSF, 1996) The map was developed to show that the locations were distributed throughout the city making it easy and convenient to recycle motor oil. Ventura County publicizes certified used oil collection centers (i.e., located at specified oil-change businesses, service stations, etc.) through a "Used Oil Recycling Month" and a used oil information center at public events, including the County Fair, Cinco de Mayo, Earth Day, and used car swap meets (Camacho, 1995). Other elements of Ventura's program include developing curriculums to be incorporated into adult education courses, such as auto repair courses, driving schools, and traffic schools.

Table 4-2. Information Collected on Landscape Maintenance and Pesticide Use

Program	Materials Reviewed	State	Region
Massachusetts OTA	Program information, fact sheet	MA	1
New Jersey Environmental Federation	Program information	NJ	2
Alexandria Sanitary Authority	Program information	VA	3
Maryland Department of Agriculture	Program information	MD	3
University of Maryland	Video, guide book, PSAs, displays	MD	3
Alliance for the Chesapeake Bay	Fact sheet	VA	3
Virginia Polytechnic Institute	Brochure	VA	3
Virginia Cooperative Extension	Program information	VA	3
Rouge Program Office, Michigan	Program information	MI	5
Wisconsin DNR	Fact sheet	WI	5
City of Greenville	Program information, brochures, PSAs	TX	6
City of Oklahoma City	Program information	OK	6
Montana Department of Environmental Quality	Program information	MT	8
City of Tempe	Program information	AZ	9
Palo Alto RWQCP	Program information, reports	CA	9
Alameda Countywide Clean Water Program	Booklet, brochures, fact sheets, posters	CA	9
Union Sanitary District	Program information	CA	9
City of Sacramento Stormwater Program	Brochure, booklet	CA	9
Santa Clara Valley Nonpoint Source Pollution Control Program	Brochure	CA	9
City of Sunnyvale	Booklet	CA	9
San Francisco Estuary Project	Guide book	CA	9
City & County of San Francisco	Brochure, inspection program	CA	9
Central Contra Costa Sanitary District	Program information, brochures	CA	9
City of Hayward	Program information	CA	9
Seattle METRO	Program information	WA	10
King County, Washington	Brochures	WA	10
US EPA	Brochures		
Farm*A*Syst/Home*A*Syt	Program information, brochures		

4.2.4.2 Vehicle Maintenance and Car Washing

Car care guides for 'do-it-yourselfers' have been developed by agencies including CCSF and Eastern Municipal Water District. Home maintenance guidebooks and brochures developed by agencies including the San Francisco Estuary Project and the Alameda Countywide Clean Water Program include recommended practices for car care as well (SF Estuary Project, 1992; ACCWP, 1995). Recommended practices include washing cars on lawns or unpaved surfaces, recycling used motor oil and antifreeze, repairing leaking vehicles promptly, cleaning up spills with absorbants, such as cat litter. In addition, outreach materials remind residents never to pour used motor oil or antifreeze down an inside drain or a storm drain.

CCSF conducted an outreach program targeting young males, ages 16-25, based on research indicating that this is the group most likely to change their own motor oil. (CCSF, 1996) Elements of the program included advertising on youth oriented radio stations, conducting promotional events at auto supply stores and distributing recycling kits, including a map showing collection center locations; the car care guide, *Fix It!*; and a used oil recycling container. Street signs placed on utility poles were also used to encourage used oil recycling.

The following entities indicated that they have programs targeting used motor oil and residential vehicle maintenance activities and provided information for this project:

Palo Alto RWQCP, CA
King County Hazardous Waste Program, WA
Central Contra Costa Sanitary District, CA
City of Phoenix, AZ
Massachusetts Office of Technical Assistance
Montana Department of Environmental Quality
City and County of San Francisco, CA
Alameda Countywide Clean Water Program, CA
City of Davis, CA
San Francisco Estuary Project, CA
Dade County Department of Environmental Resource Management, FL
Alliance for the Chesapeake Bay, VA
Rouge Program Office, MI
Eastern Municipal Water District, CA
City of Sacramento, CA

4.2.5 Home Painting Activities

Paints are a source of certain metals and solvents as described in Chapter 3.0. Painting activities conducted by do-it-yourselfers should follow the same BMPs recommended for painting contractors in Chapter 3.0. Outreach to home painters is included in home maintenance guides such as those prepared by Palo Alto RWQCP, the Alameda Countywide Clean Water Program, and the San Francisco Estuary Project. The primary messages are to wash painting equipment in indoor sinks not outside near storm drains; reuse paint thinners; and to dispose of paints, solvents, and thinners at household hazardous waste collection centers (ACCWP, 1995).

A list of entities that provided information for this project and who indicated that they have programs targeting residential painting activities include:

Palo Alto RWQCP, CA
King County Hazardous Waste Program
City of Phoenix, AZ
Massachusetts Office of Technical Assistance
Montana Department of Environmental Quality
City and County of San Francisco, CA
Alameda Countywide Clean Water Program, CA

4.2.6 Household Cleaners and Other Consumer Products

Household cleaning products have been identified as being a significant source of arsenic, cadmium, chromium, and nickel (WTC, 1992). CCCSD estimated that household products accounted for 67% of CCCSD residential arsenic loadings, 35% of CCCSD residential cadmium loadings, 20% of CCCSD residential chromium loadings, and 10% of CCCSD residential nickel loadings (LWA, 1994a). Studies conducted by the Washington Toxics Coalition and the City and County of San Francisco provide a good summary of information regarding household products.

A Seattle study conducted by the Washington Toxics Coalition (WTC), in cooperation with Seattle Metro, examined metals content and consumer usage statistics for numerous household products, including laundry detergents, dish cleaning products, bleaches, general purpose cleaners, toilet bowl cleaners, and dandruff shampoo (WTC, 1991). This study determined that, with the exception of arsenic, dish and laundry cleaning products are an essentially insignificant residential source of metals. (These products were estimated to contribute 40% of the total loadings of arsenic to the residential sewer.) None of the metals examined were found in significant quantities in general purpose cleaners and toilet bowl cleaners. Finally, the WTC tested one brand of dandruff shampoo and found it contained significant quantities of zinc; however, no zinc loadings emanating from this product category were estimated because of insufficient information on metals content and overall usage.

The study also evaluated toothpaste, hair coloring products, bar soaps, bath crystals, and metal polishes. In addition, several brands of "ultra concentrated" laundry detergents were studied to supplement results obtained from the previous two phases of the study. Household products were analyzed for arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Of the 7 different brands of toothpaste examined in the WTC study, trace elements were not found at significant levels in these products, with the exception of one brand which contained unusually high levels of zinc. However, because the market share of this brand was estimated to be only about 1%, it is not believed to contribute substantially to residential zinc loadings. Of the 15 different hair coloration products, trace elements were not found at significant levels in these products either, with the exception of one anti-graying product which contained unusually high levels of lead; however, because the overall usage quantities of this product are small, it is not believed to contribute substantially to residential lead loadings. Of bar soaps, bath crystals and metal polishes, none of the brands tested contained metals in quantities significant enough to contribute substantially to residential trace element loadings. Moreover, the examination of ultra-concentrated laundry detergents showed considerably lower levels of arsenic than those found in most other brands in earlier studies examining these products.

The Seattle study also examined 15 different brands of cosmetics, including eye and facial cosmetics of various colors. It was found that several of the brands were extremely high in zinc and chromium, while one brand was exceptionally high in cadmium. Arsenic, copper, lead, and nickel did not appear to be present in significant quantities. It was noted, however, that literally thousands of cosmetics products are on the market, and metals content (as judged from the small cross-section of products tested in the WTC study) is likely to vary greatly. Moreover, the amounts of these products entering the residential sewer are very difficult to quantify, and no attempt was made to do so. An accurate assessment of residential metals loadings from cosmetics products would therefore be a substantial research project all by itself.

CCSF conducted a study of household product contributions of heavy metals to the residential sewer (CCSF, 1991). The types of products investigated in the San Francisco study included hair products, toilet bowl cleaners, bath soaps, deodorants, and toilet paper. Information from previous studies was also incorporated into the analysis.

Using analytical results of consumer product trace element content, market share statistics, and existing data on residential and municipal wastewater, percent metals loadings to the residential sewer from household products were estimated. The San Francisco study found that the above product categories contributed less than 10% of the total residential loading of every parameter except arsenic (35%), and less than 2% of all the remaining parameters except chromium (6.9%), and silver (3.8%). Of the above product categories, powder laundry detergents were the major source of arsenic. These results indicate that, for most parameters, the above household product categories are insignificant sources of total residential trace element loadings to the sanitary sewer.

4.2.6.1 Green Cleaning Kit

An example of outreach to discourage the use of certain household products is Seattle's Green Cleaning Kit (Frahm, 1995). Since 1992, in a program funded by the local hazardous waste management unit, Seattle has given away or sold over 12,000 Green Cleaning Kits to its residents. The kits, which include spray bottles, recipes and some ingredients for non-toxic household cleaners, come in a box with instructions. Seattle instituted this program to raise citizen awareness and change behaviors. On the basis of follow-up surveys, Seattle determined that thousands of kit purchasers (up to 63%) now use the green recipes as a part of their regular household cleaning chores. Furthermore, the surveys determined that use of the Green Cleaning Kit reduced the quantity and use of hazardous cleaning agents by 15% to 30%.

Among the entities that provided information for this project and that indicated that they have programs targeting household products are:

Palo Alto RWQCP, CA
King County Hazardous Waste Program, WA
Central Contra Costa Sanitary District, CA
City of Phoenix, AZ
Massachusetts Office of Technical Assistance
Montana Department of Environmental Quality
City and County of San Francisco, CA
Alameda Countywide Clean Water Program, CA
City of Davis, CA
San Francisco Estuary Project, CA
Dade County Department of Environmental Resource Management, FL
Alliance for the Chesapeake Bay, VA

Rouge Program Office, MI
Eastern Municipal Water District, CA
City of Sacramento, CA
New Jersey Environmental Federation
Save The Bay, RI
City of Tempe, AZ
Union Sanitary District, CA
Alexandria Sanitary Authority, VA

4.2.7 Pools and Spas

Pool and spa water containing chlorine can be toxic to aquatic life. In addition, certain pool algicides contain copper which is of concern to both wastewater and stormwater systems. Public outreach has been conducted in some communities to encourage residents to dechlorinate pool water and not use copper-containing algicides. Recommendations regarding dechlorination include letting the water sit for two weeks or adding sodium bisulfate. Organic algicides are recommended as alternatives to copper-containing compounds. It is also recommended that filter rinsewater be disposed of on soil rather than down the storm drain. Some communities recommend discharging pool water to the sanitary sewer after contacting the local wastewater discharge authority (ACCWP, 1995; SF Estuary Project, 1992).

Several entities provided information about their programs targeting pools and spas, including:

Palo Alto RWQCP, CA
City of Simi Valley, CA
Alameda Countywide Clean Water Program, CA
San Francisco Estuary Project, CA
City of Sacramento, CA

4.2.8 Root Control Products

CCCSD evaluated copper sulfate root control products and estimated that these products contributed an average of 22% of the CCCSD residential copper loadings (LWA, 1994a). In the CCCSD service area, surveys indicated sales of about 3,400 pounds of root destroyer in 1992. This product is placed directly down the drain by homeowners in accordance with the instructions that come with the product. The intended use of this product is to inhibit root growth in sewers, although copper sulfate products are usually only moderately effective.

Because copper is a pollutant of concern to the entire San Francisco Bay Area, a regional approach discouraged using copper sulfate as a root control product (SFRWQCB, 1994). A regional brochure was developed describing the issue and alternative practices to remove roots from sewer lines. The brochure was distributed by POTWs throughout the Bay Area. Outreach was conducted to plumbers and hardware stores asking them not to use or sell these products.

In addition to outreach efforts, a legislative approach was used, as well (PARWQCP, 1996). During 1994, Palo Alto RWQCP staff developed and co-sponsored a bill, which was taken to the California State Assembly, that would have banned the sale and use of the copper-based root killer. This effort received support from several of the Bay Area public agencies through a letter writing campaign and participation in public workshops and legislative hearings. The legislative effort resulted in a commitment by the California Department of Pesticide Regulation to develop regulations relating to copper-based root killer. After a year of technical studies, public outreach, and regulation development, the Department of Pesticide Regulation adopted emergency regulations in December, 1995 prohibiting the sale and use of copper-based root control products in the nine Bay Area counties. In the summer of 1996, this became a permanent regulation.

CHAPTER 5.0

PUBLIC EDUCATION PROGRAMS

Educating a community's residents and businesses concerning wastewater and stormwater issues is an essential element of a nonindustrial pollution prevention or stormwater program. Public agencies throughout the country have developed public education materials. This chapter presents information regarding messages used in pollution prevention and stormwater education, audiences addressed, outreach approaches used, the watershed management approach, and use of behavior change principles.

Examples of public education materials and supporting documents were requested from agencies and private companies from around the United States. Nearly 500 brochures, flyers, door-hangers, videotapes, school program outlines, give-aways, posters, bumper stickers, and guide manuals were received from 75 public education program managers in 23 different states from all 10 US EPA regions. The agencies that provided public education materials for this project are listed in Appendix D. Several brochures, pamphlets, booklets, and other examples that were reviewed for this study have been copied and included in Appendix E. They illustrate how many agencies are communicating messages to their various audiences, including the use of regional characters, text and illustrations that target certain pollutants, activities, and audiences, and a discussion of creative outreach strategies. The appendix includes the names and telephone numbers of the agencies that produced each of the examples.

5.1 Stormwater and Pollution Prevention Messages

Public education programs heighten general awareness of stormwater and wastewater issues and communicate messages concerning specific pollutant sources. Elements of these messages, including general message themes, regional flavor of messages, and specific messages used in stormwater and wastewater pollution prevention programs, are covered in the following subsections.

5.1.1 General Message Themes

Materials provided for this study related to stormwater and urban runoff pollution typically focused on educating the general public that, as individuals, *they* are the nonpoint sources contributing every day to the most significant water pollution problems still remaining in the country. The materials usually stressed that the protection and future enjoyment of local bodies of water depend upon the individual's efforts to make the changes necessary to reduce their portion of the pollutant load. Most of the public education materials included lists of activities that people could do to reduce pollutants.

Public education programs also submitted materials that target the prevention of pollution to local wastewater treatment plants and subsequent effluent discharges to rivers, lakes, or bays. Similar to the stormwater and urban runoff programs, the messages for the pollution prevention public education programs emphasized the role and responsibility of the individual. Instead of warning people not to pollute local bodies of water via storm drains, these public education materials emphasized toxic materials that should not be discarded down house drains. Messages also informed that alternative products were readily available to replace the use of toxic cleaning and pest control materials in the home. The public education programs also emphasized taking left-over toxic wastes, including motor oil and paint, to household hazardous waste collection facilities.

5.1.2 Regional Flavor of Messages and Graphics

While basic messages on the need and how to reduce water pollution are fairly uniform throughout the U.S., the means of communicating this information have definite regional flavor. In Palo Alto, California, Flo the Raccoon is a delightful mascot. Clean Water Raingers (sic) in Trenton, New Jersey, include Claudine Crab, Diesha Diamondback (turtle), and Howie Heron. Materials from Miami, Florida, feature Officer Snook and communicate issues about the high water table and manatee protection. Some materials from Albany, New York, reflect the local interest in the arts by showcasing paintings of scenes in New York's watersheds. Fact sheets from Providence, Rhode Island, relate urban runoff pollution to the loss of shell fishing areas. The most exciting materials key into the local interests of their audiences and use regionally appropriate graphics.

Different regions of the U.S. focus on different pollutants in their public education programs. Nutrients are the focus of most programs in the East and for inland watersheds. Urban and coastal watersheds tend to focus on toxic pollutants.

The messages being conveyed to the general public are similar throughout the country. However, there is no single phrase that wraps everything up neatly—a phrase such as "Give a hoot- -don't pollute." The nationwide effort to educate the public on stormwater and pollution prevention issues would benefit greatly if such a common phrase were developed and uniformly used.

5.1.3 Specific Messages Used in Public Education Programs

Examples of messages illustrating both the similarities and the creative differences of stormwater and pollution prevention programs throughout the U.S. are presented in the following sections.

5.1.3.1 Stormwater/Urban Runoff Pollution Public Education Messages

As indicated above, public education messages either heighten general awareness of stormwater pollution or address specific sources of stormwater pollution. Messages being communicated by stormwater programs regarding general awareness include:

- ♦ Stormwater and urban runoff are not treated; therefore, as these surface flows reach local bodies of water, they contain all of the pollutants that accumulate from everyday living and commerce.
- ♦ By making changes in daily habits, individuals can protect the health of local creeks, streams, rivers, lakes, bays, and oceans.

Messages addressing specific sources of stormwater pollution include:

- ♦ Educating the general public that specific sources of stormwater pollution include automobile products, vehicle maintenance operations, litter, pet wastes, pesticides, fertilizer, erosion from construction sites, and illegal sewer connections.
- ♦ These pollutants enter the storm drain as water from rainfall, overwatering, or cleaning operations washes over outdoor surfaces.
- ♦ Specific outreach messages to businesses and/or groups typically revolve around encouraging the business to implement BMPs for their particular activity.

Examples of approaches to heightening general awareness from different parts of the country are:

California. Outreach to residents of multi-family buildings carries the following message.

"Storm Drain Pollution – Palo Alto's storm drains -- including drains in carports and parking lots -- flow directly into our creeks and San Francisco Bay with no wastewater treatment! *Remember that any substance dumped or spilled into a storm drain contaminates our local waterways and harms wildlife!*"(PARWQCP, no date, Guidelines for residents of multifamily buildings).

Washington. Outreach encouraging businesses to be aware of stormwater issues is expressed in a brochure with the following message.

"King County Promotes Your Business for Your Pollution Prevention Efforts -- Polluting is like pouring money down the drain -- it costs less to prevent it than to clean it up. It's also against the law. When it rains, water carries pollutants into storm drains that lead to lakes and streams. To prevent pollution, sweep your parking lots, cover dumpsters and stored materials, and wash cars in contained areas. Get recognized for protecting water quality -- Become a Business for Clean Water Today" (King County Surface Water Management Agency, no date, Stop Pouring Money Down the Drain).

Louisiana. Louisiana Department of Environmental Quality (DEQ) presents the following information regarding changing daily habits in a brochure entitled "Louisiana Storm Drain Stencil Program" (Louisiana DEQ, no date).

"Where should wastes go? Now that you know the dangers of dumping wastes, what is your alternative to getting rid of it? Recycle when possible. Most products like motor oils and paint thinners can be recycled and reused. Make these good habits in using household cleansers and materials: recycling, reusing and swapping. Contact local authorities for information."

The DEQ also has a series of pamphlets specifying BMPs for general audiences, urban area residents, contractors, agriculturalists, foresters, and residents with septic tanks.

Florida. Sarasota County developed a brochure called the "Bay Repair Kit" that has the following message.

"You can do something significant to improve this corner of the planet. Most pollution to our nearby bays and other waterways comes not from one or two big dirty industries, but from ... each one of us" (Sarasota County, no date).

New York. A brochure educating the public about New York watersheds uses this message:

"We all share the problem. We used to think that most water pollution in New York was caused by 'someone else' – the local sewage treatment plant, the factory down the street, the mysterious pipe emptying strange-smelling liquid into a stream. If we looked, eventually, we would find a pipe or a 'point source' of pollution.

Today, we know that the source of most water pollution is not as easily identified as a pipe ... in over 90 percent of the state's waters that are polluted, the cause can be traced to non-point sources of pollution ..."(Soil Conservation Service, 1994).

Chesapeake Bay. "A Citizen's Guide" distributed by the Chesapeake Bay Program states: "... the Chesapeake Bay is among the most productive estuaries in the world. But the Bay and its watershed are in trouble. Years of use — and abuse — have taken their toll...The future of the Bay depends largely on the choices we make today — not only for the 13.6 million people who currently live here, but for the 2.6 million more of us expected to make this region home by the year 2020" (Chesapeake Regional Information Service, no date).

Examples of stormwater messages targeting specific sources are shown in examples from Sacramento and Santa Clara Valley. The Sacramento Stormwater Management Program describes practices targeting several sources in the brochure, "Solution to Stormwater Pollution," which is available in English and Spanish.

"What Can You Do to Prevent Stormwater Pollution? You can make a big difference in keeping the creeks and rivers in the Sacramento area clean and healthy for fish, plants, birds, and wildlife, and ourselves by following these tips:

- Get involved! Stencil a storm drain with the message *'No dumping! Flows to river.'* Clean a creek. Call your local agency for more ideas about how you can help.
- Never pour anything down a storm drain that you wouldn't want to swim in!
- Try to use up toxic products or buy smaller quantities so you don't have to worry about disposing of leftover materials.
- Bring leftover toxic materials such as paint, cleaners, used motor oil, and pesticides to a household hazardous waste collection event in your community or to an authorized drop-off point.

- Never hose down spills into a storm drain. Use kitty litter or other absorbent material to clean up spills of toxic materials from pavement.
- Use pesticides, herbicides, and fertilizers carefully and sparingly, and do not apply if rain is forecast.
- Keep your vehicle and equipment well tuned to avoid leaks.
- Use public transportation or car pooling. When it rains, air pollution becomes water pollution!
- Keep yard clippings, detergent, trash and animal waste out of the gutter and storm drains."

The Santa Clara Valley Nonpoint Source Pollution Control Program presents information for a specific source in a poster for restaurants "Good Cleaning Practices to Protect Our Creeks and Bay" (SCVNSP, no date).

> "Clean all floormats, filters and garbage cans in the mop sink ...
> ... or outside in a bermed and covered area.
> Pour washwater into the mop sink
> Use a dry method for spill cleanup
> Keep dumpster area clean and the lid closed
> Handle and dispose of grease properly".

The poster is illustrated with large, interesting drawings that show how to perform each of the good cleaning practices specified. It is also accompanied by a packet of educational information for restaurant managers, with a checklist of BMPs for employees. The checklist has been printed in several languages.

5.1.3.2 Common Messages for Wastewater Pollution Prevention Programs

The three most commonly used messages related to wastewater pollution prevention (inside homes and businesses) are:

- ♦ To protect local bodies of water, it is important to avoid pouring toxic chemicals down drains that lead to the sanitary sewer system.

- ♦ Most informational materials emphasize alternatives that can readily replace household products that are toxic to the environment.

- There are properly designed and controlled facilities to safely dispose of household hazardous wastes in most areas of the country. The public is usually provided with the telephone numbers and other information necessary to make arrangements to properly dispose of common toxic wastes.

Several jurisdictions offer examples of how these messages are communicated:

California. East Bay Municipal Utility District (EBMUD) provides general information about the role of wastewater treatment in its brochure "Stopping Pollution at the Source."

"For living organisms from plankton to people, San Francisco Bay is a source of life, pleasure and nourishment. It's also a place where treatment plants, like EBMUD's, release highly treated wastewater from homes and industries. Discharges from our plant form a tiny part of the Bay's waters. Still to keep those releases free of harmful toxins, EBMUD created an award-winning Source Control Program. The District keeps pollutants out of the Bay by making sure homes, businesses and industries keep them out of sewers" (EBMUD, 1994).

The San Francisco Estuary Project describes household hazardous wastes in its brochure "Estuarywise."

"Inside your home ... Your cupboards and closets contain dozens of everyday cleaning, polishing, and painting products hazardous to our waterways. Under the sink lurk the drain openers, oven cleaners and insect sprays; out in the laundry room the chlorine bleaches and spot removers; down in the basement workshop the glues, paints and wood preservatives. Amazingly enough, these and other common household items can add up to a considerable source of pollution, once they find their way from our homes to the Estuary via drains, toilets and your local landfill. And don't forget that leaky faucet in the bathroom guzzling our scarce freshwater supply. ... Tackle it without toxics..." (SF Estuary Project, 1992).

Arizona. The cities of Phoenix, Glendale, Mesa, Peoria, Scottsdale, Tempe, and Gilbert produced a brochure called "Pollution Prevention Begins with You -- A Guide to Protecting the Salt River and Our Environment." Instead of reinventing the wheel, it adapted text and graphics used in a brochure that originated in the Santa Clara Valley Nonpoint Source Pollution Control Program. Its key messages are:

"How you use and dispose of products containing toxic substances has a direct impact on the environment and our quality of life ... Before you pour anything down the drain, stop and think" (City of Tempe, no date).

The City of Tempe has produced other good materials that inform the general public about pollution prevention in a program that "stresses a multi-media approach to reduction and control to prevent the transfer of pollutants from one medium (air, land, and water) to another" (City of Tempe, no date, Our Environment -- Our Choice). The public works department distributes a list of "Safe Alternatives to Common Household Chemicals" (City of Tempe, no date) for the residential population and a newsletter for its industrial dischargers (City of Tempe, 1996).

New Mexico. The city of Albuquerque relates household practices to local waterways in its brochure, "Are You Pouring Water Quality Down the Drain?"

"[The following are headings of sections in the brochure.] What goes down the drain does not simply go away... Did you know that many substances that enter the sewer system can't be removed during the treatment process?... It may surprise you to find out that the Rio Grande supports a riparian habitat along its banks. ... The natural life of this habitat is endangered by substances that cannot be removed in treatment. ... That's why your decisions count. ... Sometimes, the individual can make a big difference! ... A thoughtful home owner has many alternatives to pouring toxins down the drain" (City of Albuquerque, no date).

5.1.4 Best Management Practices for the General Public

One approach to communicating messages targeting specific sources is to develop BMPs for the general public. Much of the literature reviewed in this study includes BMPs or actions that people can take to reduce the flow of pollutants to their local water resources. These are often accompanied by illustrations to clarify how certain activities are done. The target audiences vary widely from community to community in the U.S. Some agencies provided public education materials that focus entirely upon the general public. Others had materials for a range of target audiences, with BMPs specified for their unique roles in the community. In general, BMPs for residents focus on using more elbow grease and fewer chemicals to clean up after ourselves.

Examples of BMPs recommended for stormwater and urban runoff pollution prevention are:

The New Jersey Department of Environmental Protection in Trenton, New Jersey, has developed a brochure, "How to be a Clean Water Rainger (sic)." Below is the approach used in the brochure to describe BMPs for the general public.

"Top Ten Things You Can Do to Help Keep Water Clean:

- Never throw anything down storm drains. They are for rainwater only.
- Don't litter. Always put trash where it belongs.
- Always clean up after your pets. Obey your town's 'pooper scooper' laws.
- Tell others how important it is to keep our land and water clean.
- Plant a tree. They take pollutants out of ground water, provide shade, and clean the air.
- Find out what waterway you live near. Where does your water come from?
- Precycle! Buy products that use the least amount of packaging.
- Recycle. Find out what is recyclable in your community. Buy products in recycled or recyclable containers.
- Learn about environmental issues. Get involved in local organizations.
- Conserve water whenever possible. For example, turn off the water while brushing your teeth and don't linger in the shower."

The City and County of San Francisco has developed a fan-style publication "Grow It! The Less-Toxic Garden. Control Pests & Plant Disease Using Less-Toxic Methods" educates the public on pesticide alternatives. It is available in several languages. Approximately 30 "less toxic control methods" are listed in this easy-to-use publication for common pests, mildews, and plant diseases. Among them are the following:

- "Aphids - - Spray with insecticidal soap (available in nurseries). Always test a small portion of foliage before treating the entire plant. Some plants are very sensitive to soap sprays.
- Cutworms - Hand pick during the day searching in widening rings around the stems of seedlings.
- Earwigs - Set out short lengths of bamboo or rolled up newspaper to trap earwigs. Check in the morning and shake earwigs into a bucket of soapy water.
- Powdery Mildew - Wash new growth with a spray of ordinary water. Powdery mildew thrives in cool, dry conditions."

5.1.5 Messages Targeting Specific Sources For Wastewater

Several agencies have developed materials addressing toxic pollutants coming from household and garden products. These are often directed towards reducing pollutants in the sanitary sewer system; however, most are applicable to stormwater/urban runoff pollution prevention, as well. Educational materials have been developed to give the general public information about natural alternatives to toxic products. These sometimes use a creative format, such as recipe cards, wheels to "dial" to the safer alternative, and posters for workshop or kitchen. The examples included below were selected to show the creativity that agencies have used to communicate natural (nontoxic) alternatives to the general public.

Examples of materials that describe nontoxic alternatives and disposal practices associated with prevention of pollution to the sanitary system are:

The City of Sunnyvale, California, has developed recipe cards for household activities (City of Sunnyvale, no date). Recipe cards are available for insecticidal soaps, odor removers, cut flower preservers, methods to apply flea powder, non-chemical drain cleaner, organic pest repellant, pantry pest repellants, baking soda play clay, air fresheners, wood furniture polish, metal polishes, abrasive cleaners, ant repellant, window cleaner, moth preventative, and roach repellant. One example is using olive oil combined with vinegar or lemon juice as furniture polish.

EBMUD produced a 'wheel' describing recommended alternatives to several household products (EBMUD, no date). For each product/chemical listed, the 9-inch diameter wheel includes hazardous ingredients, alternatives, hazardous properties, and proper method of waste management. The following are examples of alternatives for common hazardous products:

- "Paint thinners and turpentine -- Use water in water-based paints.
- Flea collars and sprays -- Herbal collar/ointment (eucalyptus or rosemary), or Brewer's yeast (call vet for amount).
- Herbicides -- Hand weeding, let grass grow 2-3 inches to shade weed seedlings."

A Florida brochure addressing pesticides, hazardous wastes and leftover paint presents the following BMPs (Florida Department of Environmental Protection, no date):

- "Follow label instruction on rinsing empty containers of garden chemicals. Apply the rinse water to the same plants that received the pesticide. Then, dispose of the empty, clean containers as solid waste. ...

- To properly dispose of leftover hazardous wastes, hazardous materials and other chemicals, take part in local 'Amnesty Days.' Call your local government. Many counties operate temporary hazardous waste storage areas which may be available to homeowners who have materials they need to dispose of.

- Donate half-full cans of paint to groups that can use them such as homeless shelters, Habitat for Humanity, or similar organizations."

5.2 Audiences

Every community has audiences composed of the general public, school children, businesses and industry, and municipal government. Subsets of these audiences vary by community. The target audiences identified for the Milwaukee area are representative of typical audiences in many communities (Southeast Area Water Quality Education, 1994). They include:

- **"Urban residents**
  - Residents with yards and gardens
  - Vehicle owners
  - Pet owners
  - Schools and youth groups
  - Community groups

- **Local governments**
  - Elected officials
  - Staff and consultants

- **Business and industry**
  - Automotive businesses
  - Building maintenance
  - Construction
  - Fleet maintenance
  - Landscaping and related businesses

- Marinas and boat maintenance
- Mobile cleaning services
- Outdoor storage and processing
- Parking lot and grounds maintenance"

This list represents the majority of audiences and more focused groups targeted by most of the larger communities throughout the country. Additional sub-groups reflect the character of a particular region—farmers in agricultural areas, foresters in the timber industry, homeless camps in big cities, and mining companies.

Certain sub-groups are just emerging as targeted audiences: ethnic employees of businesses who may not speak the same language or share environmental values with the managers/owners of the firm; new development, including architects, planners, engineers, and developers; customers of automobile parts stores who often arrive in the parking lots of these stores with problematic cars leaking oil and other pollutants; and watershed conservancies and stakeholders programs. These groups, which have unique roles in the social and business communities, are just beginning to be targeted by public education programs (Brosseau, 1996).

Approaches to different audiences including the general public, ethnic communities, businesses, municipal employees and the emerging sub-groups just mentioned are described below.

5.2.1 The General Public

Every agency that provided public education materials for this project included at least one item that targets the general public, "the average citizens of the community." In certain larger cities, key materials were translated to languages other than English (primarily Spanish and Chinese). When looking at the materials that were more successful than others in communicating stormwater and pollution prevention information to the general public, the following common threads stood out:

- ♦ Public education programs for the general public audience focused on communicating the key messages listed earlier in this chapter; the specific local creeks, streams, rivers, lakes, bays and/or oceans that were affected by pollution; and local, State, or national (US EPA) telephone numbers to call for more information.

- ♦ The best materials use layman's language, are highly visual, relatively brief, and focus on the tools for behavioral modification.

- Graphics did not have to be highly professional to be effective, but the materials that were easiest to read and understand have more graphics than text in the overall composition.

- The materials were designed to be succinct, deliver the key messages quickly and clearly, and provide the tools to go out and do the job right.

Some agencies are opting for the money-saving policy to "not reinvent the wheel" and have adapted public education materials that were originally prepared for another community (e.g., the City of Phoenix adapted its brochure "Pollution Prevention Begins With You -- A Guide to Protecting the Salt River and Our Environment" from a publication prepared for the Santa Clara Valley Nonpoint Source Pollution Control Program.) There are some limits to the ability to adapt materials produced by others, particularly if the item has a strong regional flavor that doesn't easily translate to another part of the country.

5.2.2 Ethnic Communities

Media coverage and workshops are two methods used to outreach to specific ethnic groups. Good examples are programs conducted by the cities of Los Angeles and San Francisco. The City of Los Angeles stormwater program prepared public service announcements targeting the Latino community and received overwhelming play on Spanish radio stations in Southern California. CCSF conducted workshops for the African American and Latino communities. Demonstrations on safer cleaning methods were conducted at supermarkets and house parties. San Francisco also held workshops for Latino house cleaners focusing on potential health problems associated with certain cleaning chemicals and their environmental impacts (CCSF, 1996).

Another strategy that has been used to reach certain demographic groups is to provide consumers with stormwater/urban runoff public education materials along with the products they buy in a point-of-purchase public education campaign. One example is a campaign that targeted not only a specific cultural audience, but a specific pollutant, as well. San Mateo County teamed up with Pennzoil in a campaign that featured, but did not focus exclusively on, an ethnic group and targeted the pollutants associated with used motor oil. This point-of-purchase campaign resulted in a 12% increase in the amount of waste oil collected locally.

Text of the campaign's printed material was presented in English only. Rich-looking visuals featured a Latino man. Research showed that, in the San Mateo area, most people who changed their own oil were young men, and many of them are Latino. Therefore, the campaign was designed to target this audience (Boyd, 1996).

As already mentioned, in larger communities, many print materials are prepared in multiple languages, using similar graphics and text. However, it appears that there is a tremendous opportunity to work even more effectively with ethnic communities in America by following the examples of Los Angeles, San Francisco, and San Mateo. This concept is more than translating a piece prepared in English to another language; it is having the targeted ethnic community in mind at the outset.

Surveys and focus groups help program managers understand the priorities of ethnic communities. For example, a public awareness survey conducted for the Los Angeles County Department of Public Works showed that Latino respondents were most concerned about reducing pollution in waterways than any other group; and that the greater concerns for all ethnic groups were reducing crime and gang violence, drug abuse, improving the quality of public schools, and creating jobs (LA County Department of Public Works, 1996).

5.2.3 Business Audiences

Public education programs approach businesses in various ways. The most direct of these is educating business managers and employees about how their practices may harm the environment and the changes they can implement to make corrections.

Many business education materials also cite regulations. For example, the (San Francisco) Bay Area Stormwater Management Agencies Association and the San Francisco Regional Water Quality Control Board produced a brochure targeting mobile cleaners called "Pollution from Surface Cleaning" (BASMAA, 1996). The brochure states:

> "Pollution from surface cleaning ... It harms the environment .... And it's against the law! Allowing polluting substances into storm drains is prohibited in California. Both the person who discharges the pollutant or leaves it behind, and the owner of the property where the material is generated are liable."

The brochure then describes the BMPs available to mobile cleaners.

At a recent training workshop for mobile cleaners in the San Francisco area, the cleaners stated that they were always "looking over their shoulders" because they didn't know whether or not they were following the correct procedures. The first of three training workshops provided BMP information using slides and a hands-on demonstration to educate over 90 people providing this service (Brosseau, 1996).

Other approaches to working with businesses are discussed below and include point-of-purchase displays, business recognition programs, educational materials, and ethnic employee training.

5.2.3.1 Point-of-Purchase

The greatest emphasis of public education programs oriented to the business audience is to win cooperation, save companies money, and to form partnerships that place businesses in a positive light in their community. Some of the most effective business outreach efforts are highly focused. One example is the point-of-purchase waste oil recycling campaign in San Mateo, California. Local oil distributors were provided with kits, stormwater education brochures, and a stand-up display, all of which encouraged the do-it-yourselfer to recycle motor oil. Retailers were responsible for distributing and replenishing the supplies of brochures and kits. Distributors were "on-board" as willing partners and have indicated that they want to participate in a repeat campaign (Boyd, 1996).

5.2.3.2 Business Recognition

Several pollution prevention programs use business recognition to encourage environmental stewardship. Examples include the King County Surface Water Management Program; Manhattan Beach, California's the Clean Bay Business program; the City of Los Angeles initiated the Ocean Safe Coalition of Businesses; and the Association of Bay Area Governments promotes the Green Business Program. The literature of the Alameda County Green Business Program, which is similar to many other clean business outreach efforts, states:

> "The Green Business Program recognizes businesses that are in compliance with environmental regulations and have taken steps to conserve water, energy, and other resources. Participating shops receive a number of benefits from the program including positive public recognition [and] streamlined compliance and pollution prevention assistance" (Alameda County, October 1996).

Another example of outreach that involves a city's recognition of environmental responsibility is the City of Palo Alto, California's official "Pollution Prevention Week," (September 16-22, 1996). The Mayor issued a proclamation that stated:

> "Pollution Prevention Week is an opportunity for government, industry, and environmental organizations to recognize the potential of pollution prevention and to work together to plan for a prosperous and sustainable future" (City of Palo Alto, July 1996).

5.2.3.3 Educational Materials for Businesses

Just as regions of the U.S. are quite unique from one another, types of businesses have particular characteristics, as well. Materials targeting businesses are more likely to be used if they use a design that is compatible with the industry. For example, a brochure prepared for the food service industry in the Santa Clara Valley area of California to communicate stormwater education/BMPs is subtly similar to menus found in fine restaurants (Santa Clara Valley Non-Point Source Control Program, no date, Good Cleaning Practices...). It included a poster of BMPs to be displayed in the kitchen where wall space may be a premium; therefore, both sides of the poster were used—the same graphics were printed in a horizontal format on one side and a vertical format on the other. This allows the restaurant managers to display where they have room on the wall, a cabinet, or door. Even more "restaurant-smart" thinking went into this poster: it is laminated so that kitchen grease and splatters easily wipe off.

5.2.3.4 Ethnic Employee Training

The restaurant package prepared by Santa Clara Valley was also designed to include training for employees who do not speak English. Inserts highlighting BMPs are included in Spanish, Vietnamese, Chinese, and English. The poster uses few words and, in fact, is so well-illustrated that it is not even necessary to be literate to understand what is required of the workers. The City and County of Los Angeles jointly produced a poster for training restaurant employees using a similar well-illustrated format. The text is in English and Spanish (City and County of Los Angeles, no date).

Efforts are also being made to provide environmental education/training for employees of the vehicle service industry for whom Spanish is the primary language. The City and County of San Francisco and the Commonwealth of Virginia, Department of Environmental Quality are two of the major programs in the United States that have produced training materials in Spanish for this targeted activity.

5.2.4 Municipal Audiences

Government offices are typically among the first to establish environmental policies for employees, including BMPs that apply to a cross-section of public service functions. Also, because government agencies often contract out certain services, BMP training and policies can be extended to private firms that are awarded those contracts. Examples from Florida, North Carolina, Cincinnati, and California are discussed below.

A three-phase program to reduce waste and pollution in County government offices in Broward County, Florida, is being conducted to deal with the area's problems with water pollution and dead fish (NPPR, 1995). These negative conditions affect the county's recreational boating and tourism industry. Initially, the pollution prevention education program targeted the business and industrial community. But the County decided that government workers should set an example by exploring opportunities and taking appropriate actions. The three phases include taking a survey of waste generating practices, preparing a summary report with recommendations for improvements, and implementation of a county-government wide waste reduction and pollution prevention program.

"Stormwater Fact Sheet No. 5, Municipal Pollution Prevention Planning", (Land-of-the-Sky Regional Council, no date) targets the municipal audience or government workers, including managers; the men and women who sweep streets, wash city trucks, maintain municipal landscaping, and who follow BMPs that prevent pollutants in stormwater and urban runoff.

The City of Cincinnati is attempting to conduct a model pollution prevention program in its own operations (NPPR, 1995). All departments and divisions have had training. The City invited other local and State government offices to participate in training and promotional activities. The City has adopted an "Environmental Preference" purchasing ordinance for all city purchases, such as lead-free, water-based paints for highway line striping. Cincinnati has also extended its training to the business sector.

The City of Sunnyvale Public Education staff makes presentations concerning pollution prevention to each city department annually. Presentations are geared toward information relevant to the specific department (City of Sunnyvale, 1996). Similar in-house education and training is also being done in North Carolina and other parts of the country to encourage municipal workers to serve as examples for others to follow in pollution prevention.

5.2.5 School Programs and Children

A great deal of work is currently underway targeting the audience of school children and their teachers. Materials and programs are typically directed to various age groups: grade school beginning with kindergarten, middle school/junior high, and high school.

Most school programs are targeted toward younger students. Like the campaigns to discourage smoking and encourage recycling, environmental educators hope to teach the young generation about healthy pollution prevention habits and that the students will then nag their parents and guardians to improve their own actions.

The content of school programs is extremely diverse:

The City of Los Angeles targets hundreds of grade school children at a time with its bilingual "Canopy" performances shown at assemblies in public and private schools (City of Los Angeles, 1994b).

Alameda County, California, has a popular "Kids in Creeks" teacher workshop program for grades K-12 (Alameda Countywide Clean Water Program, 1995).

The Central Contra Costa County Sanitation District's school education program goes into the classrooms with posters and displays, and a curriculum developed by a local environmentally-oriented museum. Students are enlisted in the "Central San Sewer Squad"(CCCSD, 1994).

The Seattle Drainage and Wastewater Utility distributes "Water You Doing?" for middle school classes. This has a teachers' manual, field trip directory, resource guide and activities, and three very funny and informative videos. The agency also provides equipment and training for grade school teachers in over 100 schools to raise salmon in their classrooms from eggs to fry, and then release the fry into local waters (Seattle Drainage and Wastewater Utility, 1996).

The King County Surface Water Management Division provides community stewardship grants to encourage watershed education and enhancement projects (King County Surface Water Management Agency, no date, Duwamish River Site Tour).

EBMUD, as part of its Pollution Prevention program outreach to schools, produced the student publication, "The Tardy Twins Meet Polluto," and an accompanying teacher's guide. This publication is designed to acquaint upper elementary students with the processes of the wastewater treatment and the importance of pollution prevention and controlling sources. It covers the processes of pollution and purification and the community's role in contributing to the problem and to the solution (EBMUD, 1996).

The City of Sunnyvale sponsors an environmental science fair targeting 4th to 7th graders. Projects are judged by educators and representatives from local businesses, and non-profit organizations. Projects entered in the Fair have included 'green' household cleaners, effects of urban runoff, and birds of the Bay (City of Sunnyvale, 1996).

Adopt-A-Watershed is a school education program that is used in many communities. It has curriculum and activities for grades K to high school that include long-term field studies, restoration projects, and community actions. An example of these for a kindergarten class is:

> What is a watershed? Concept -- The earth contains objects which are observably different and that change. Long-term field study--Tree height and diameter/succession study. Restoration project -- Tree planting. Community action -- Field trip booklet for family and community; children explain to family what a watershed is (Sacramento River Watershed Project, 1996).

The Water Environmental Federation is a partner with over a dozen other agencies and organizations in "Give Water a Hand — A Youth Program for Local Environmental Action." Youth groups select a problem of interest and conduct a project to solve it.

National Project WET (Water Education for Teachers) produces a wide range of materials for school programs. These include curriculum and an activity guide; science activities; booklets and handbooks on events, history, and stories; tee-shirts; and modules on the Everglades watershed, wetlands, groundwater, and water conservation (National Project WET, 1996).

The University of Wisconsin Extension, Environmental Resources Center has produced a resource series called "Blueprints for Educating Young People About Water". It encourages youth leaders to work with groups on water resource and protection projects (University of Wisconsin, no date).

The Global Rivers Environmental Education Network (GREEN) is an environmental education program that focuses on watersheds. The non-profit organization works with groups in 130 countries to promote watershed sustainability. Various materials are available through this organization: field manuals and kits for water quality monitoring, source book for watershed education, an educator's guide to toxic assessment, and several other publications and videos. Among the educational materials that are distributed by GREEN are those produced by National Project WET (see above) (GREEN, 1996).

The City of Santa Monica, California, had an interesting experience with high schoolers. These older students did not come through when they were recruited to distribute door hangers, apparently because the task felt like "make-work." However, these students were stellar when they volunteered to teach stormwater education principles to younger students in their school system. Their peer-teaching efforts were very relevant, and the benefit returned to the City of Santa Monica was quite valuable (Romain, 1996).

Public education programs targeting students should be age-appropriate, and as illustrated above, have relevance to the audience. Another thing to consider is that teachers are being overwhelmed with requests to use materials similar to stormwater education in their classrooms. How do teachers choose what to use? To avoid having resource materials gather dust on a classroom shelf, some research into the school's needs would be a benefit. For example, does the school need transportation for a field trip and could you provide that to get your program used in the classroom?

On the other hand, public education programs should also consider the cost per student. The City of Los Angeles believes that it gets great value in educating hundreds of students at a time with its exciting and sought-after performance of the "Canopy" program.

5.3 Effective Strategies for Different Audiences and Messages

A 1995 public awareness survey for the Los Angeles County Public Works Department asked people where they obtained information on the storm drain system. The responses were as follows:

Broadcast television	49%
Newspaper	47%
Radio	5%
Cable television	4%
Magazine	3%

Billboard	3%
Stenciling drains	3%
Brochure	1%
School child	1%
Other	8%
Don't know	6%

When these same people were asked where they received their information on local issues in general, they responded: newspapers (65%), broadcast television (63%), radio (24%), cable television (15%), magazines (12%), brochure (6%), newsletters (6%), billboards (5%), school child (4%), other (4%), and "don't know" (0%).

A survey conducted by researchers at the University of Wisconsin in the lower Milwaukee River Basin in 1989 showed similar results, but in addition to the media as a major source, pamphlets and newsletters were also rated highly effective.

5.3.1 Media (Newspaper, Television, Radio)

As just illustrated, using the media is one of the most effective ways to get information into the hands and minds of the general public. Effective media campaigns will adhere to the following principles:

- The viewing public needs to be rewarded, with things such as entertainment and/or information that directly helps them with a problem or saves them money. A public service announcement (PSA) that appears to serve only the needs of the sponsoring agency will fall flat.

- The piece prepared for the media needs to include basic information. The piece also needs to give people instructions; it should not simply tell the audience that water pollution is bad.

- Many agencies, when paying for advertising, are also asking for free time to increase coverage. When approaching television and radio stations to play PSAs, several agencies ask for "unsold" air time.

- ♦ When investing in the development of a PSA, public education managers may have more success if they work from the beginning with a particular radio or television station. This will not ensure that the PSA will receive good coverage, but it will help.

- ♦ PSAs have been developed to be shown in movie theaters before the previews. There is a hard and fast rule that PSAs shown in theaters must premiere at the movies. They cannot first appear on television or any other medium. Arrangements can be made with theaters that the PSAs may be shown at a later date in other venues.

Programs working effectively with media in Wisconsin and Texas are described below. As a result of the public awareness survey mentioned above, the Southeast Area Water Quality Education Program of the University of Wisconsin Extension concluded that a well-coordinated multimedia outreach program would be one of the most effective ways to convey stormwater information. The University prepared the following list outlining its media strategy:

1. Build on existing themes, mascots, and materials, especially the "It all adds up" and the "Stormie" cartoon character.

2. Target materials to reach all income, age, and cultural groups using appropriate languages, themes, music, media outlets, etc.

3. Use a variety of messages, times, and media to reach the critical threshold where people will remember and act on the information they have received.

4. Make the content and tone of messages positive.

5. Appeal to motivations, such as clean neighborhoods, health and safety, environmental quality, and convenience.

6. Build on what people already know and use sources they consider credible.

7. Use terms that people can easily understand such as "runoff" rather than "nonpoint source pollution."

8. Match the media to the message, keeping in mind that:

- Print media are most effective for more messages that require absorption of details and contemplation by the receiver;
- Television has the strongest emotional impact, but is the most costly; and
- Radio's advantages are flexibility and the ability to reach specific target audiences multiple times at a markedly lower cost than television.

9. Use graphics and sound to reinforce messages and make them more memorable.

10. Localize messages, but where appropriate, tie them to national and international events."

The efforts of Greenville, Texas, to reduce the level of the pesticide diazinon in wastewater effluent was described in a previous chapter of this report. Working with the media was a major reason why the overall pollution prevention program was successful (Erwin, 1996). Virtually every element of the total public outreach program was covered by the media. Articles were placed in the local newspaper, the City newsletter, and the "Texas Town & City" magazine. The message about diazinon use was covered in widely different ways: a local library program on the use of alternative pesticide controls, seminars given by recognized experts on fire ant control, flea and tick seminars, public awareness survey results, editorials about the public awareness survey, household hazardous waste announcements tied to diazinon use, environmental fairs, student programs, student-designed billboard contest, tours of the wastewater treatment plant, storm drain stenciling, small paid advertisements, monthly guest columns in the local newspaper, and radio PSAs.

In effect, Greenville, Texas "double-dipped": they gained public awareness through the various public outreach strategies (e.g., environmental fairs and student programs) and then gained far more exposure through publicizing their event and its message primarily in the local newspaper. As stated earlier, Greenville residents responded to this program by drastically reducing the volume of the toxic pesticide that previously caused chronic problems and violations at the community's wastewater treatment plant.

Effective media campaigns bring the issue to the forefront for the general public. Survey after survey confirms that people learn about environmental issues from newspapers, television, radio, and various publications. An effective media campaign capitalizes on opportunities for publicity. For example, the public can learn about stormwater and pollution prevention issues when they read newspaper articles about grass roots events, results of public awareness surveys, government employees featured for their efforts to implement BMPs, businesses being honored for their efforts to implement BMPs, a classroom field trip, or helpful educational materials that are available free to the public. Taken together in an effective media campaign, the message to encourage clean water practices is emphasized over and over.

5.3.2 Public Events

Earth Day was the original public event that drew the general public together to support protection of the environment. Today, agencies and organizations rarely miss participating in Earth Day festivities and often sponsor some form of outreach in a variety of public events each year. Examples of strategies using public events to promote awareness of wastewater and stormwater issues are discussed in the following subsections.

A self-guided bicycle tour of the Duwamish River was developed by the King County Surface Water Management agency in Seattle and is promoted by the Cascade Bicycle Club. A brochure, "Duwamish River Restoration Sites Tour," which includes a map for bicyclists, gives both environmental information and safety tips. This program targets the general public, bicycling enthusiasts in particular (King County, no date, Duwamish River Site Tour).

Several forms of cleanup days can be found around the country. In Sacramento, California, several groups including the Urban Creeks Council sponsor "Creek Week" that concludes with a creek cleanup with prizes for the most unusual things retrieved. This is a grass roots affair, that includes free lunch donated by a local fast food restaurant, live music, environmental education booths, and free tee-shirts. Approximately 500 people participated in the 1996 cleanup day. This type of program targets the general public with the message that individuals can contribute to cleaning up our water (Clark, 1996).

The City of Sunnyvale sponsors several public events throughout the year, including Coastal Cleanup Day for the South Bay, Pollution Prevention Week, Earth Day, and an Environmental Science Fair. On Coastal Cleanup Day, volunteers clean up local creeks and parks with 600 people volunteering in 1994 and 1,000 volunteers participating in 1995. Earth Day activities reached over 4,000 people with materials and interactive booths about nonpoint source pollution and pollution prevention (City of Sunnyvale, 1996).

CCSF recognized the diversity of its population of one million residents and prepared a catalog of all of the known community and cultural events held regularly. The catalog included information on the schedule of the events and how to contact the sponsoring organizations. The participation in these events targets the general public (CCSF, 1996).

Many cities make mini-public events from stenciling programs, bringing together people in a neighborhood to stencil their storm drains. These programs also target the general public. Almost every community that provided materials for this research study has a storm drain stenciling program. They all make a simple statement, such as "No Dumping. This drains to ocean (or bay, river, creek, or wetland)."

Major public events, such as Earth Day and the Great Coastal Cleanup, build awareness of environmental issues for large audiences. Given the large numbers of people involved and the lack of opportunity for thorough discussion of details, messages associated with these types of public events need to be simple. Smaller events, such as neighborhoods getting together to stencil storm drains, provide the opportunity for leisurely, thorough discussion of a range of environmental concerns.

5.3.3 Workshops, Trade Shows

Workshops are offered by agencies, ultimately to provide detailed information and demonstrations on how to implement BMPs. These programs often feature a related subject and piggy-back pollution prevention information.

CCSF offers workshops for the general public. Free gardening workshops are given in San Francisco to teach "less toxic gardening" to residents. CCSF also offer workshops on auto maintenance. The auto maintenance workshop features "low riders" and auto demonstrations to appeal to young males who were identified as most likely to work on their own vehicles. In addition to carrying an environmental message, the information offered is practical and useful thus filling a need of the people attending (CCSF, 1996).

A training workshop was given to mobile cleaners in the San Francisco Bay Area regarding BMPs to reduce the volume of pollutants from outdoor steam and pressure cleaning. The workshop concluded with a self-graded examination and distribution of recognition certificates. To encourage participation of mobile cleaners, the sponsoring agencies, RWQCB and BASMAA, also provided outreach to the cleaners' potential customers to encourage hiring of firms that completed this training program (Brosseau, 1996).

A conference for developers, businesses, local governments, and environmental organizations on planning for new development in Western Michigan was sponsored by the West Michigan

Environmental Action Council. It was attended by over 250 people (West Michigan Environmental Action council, no date).

Trade shows offer a forum for focused public education. For example, the City of Los Angeles developed a poster illustrating BMPs for restaurants and distributed free copies at a Restaurant and Food Industry trade show in Los Angeles. Because the cost and logistics of distribution of materials can be significant, trade shows that draw large numbers of targeted business audiences, such as restaurants, construction, and boating, are excellent venues for environmental education. The trick is capturing the attention of the participants. This can be accomplished with the same strategy as indicated for audiences reached through the media. Offer some kind of reward, such as information that will help solve a problem in their trade (Ellis, 1996).

5.3.4 Videos

Videos have also been produced pertaining to stormwater and wastewater issues. All of the videos reviewed for this study were professionally produced and targeted different audiences.

Where Does It Go? is a 12-minute video narrated by and featuring middle school age children. The video is a collaborative effort of schools in Petaluma, Novato, and Vallejo, California, with the Central Marin Sanitation District, other nearby agencies, and the California Integrated Waste Management Board's Used Oil Grants program. The key messages conveyed by this tape are that the wastewater and storm drain systems are separate; even with treatment, some pollutants still pass through the plant into the San Francisco Bay. The children narrating are clear and straightforward about what individuals can do to reduce their own pollution: wash cars at car washes instead of on the street, clean up a creek or storm drain, and use less toxic products. This is an excellent video that holds the viewers' attention, highlights the essential points related to preventing pollution in both the sanitary and stormwater systems, and provides helpful BMP suggestions. Along with the video is a lesson plan for 4th through 6th graders. The video cost $12,000 to produce. Each participating agency received 55 copies, a lesson plan, stickers, and a submaster of the video to produce additional copies (Bender, 1994).

H2O Improvements is a 20-minute program by the Massachusetts OTA (Massachusetts OTA, 1994). It focuses on pollution prevention and describes the wastewater treatment process. The video uses humorous vignettes to point out that it is less expensive to prevent pollution than it is to provide physical treatment, answers questions about the use and disposal of toxic materials, and addresses related issues

Storm Water, Clean Water Protection Program--Protecting Our Water is a 10-minute video that targets professions involved in new development: architects, developers, contractors, and maintenance (Riverside Flood Control and Water Conservation District, no date). The video was carefully made so that it has only limited reference to Riverside and, therefore, is easy to use in other regions. It uses a straightforward educational approach that combines illustrations with on-site visuals to demonstrate various BMPs that reduce stormwater pollution from design, construction, and maintenance points of view.

Water You Doing? is a 35-minute videotape with five segments. (Seattle Drainage and Wastewater Utility, 1992). Because these excellent presentations are heavily focused on Puget Sound, they are not readily adaptable for other areas. The program recognizes that to communicate water quality messages to what they call the "MTV generation," the video program would have to be different. The first segment uses a funny scientist to make the point about water sources and resources and the ways the Puget Sound is being polluted. The next segment brings together the weathermen of three local television stations to describe the watershed. The third segment uses a "Dragnet" theme to point out the difference between the sanitary and storm drain systems. The Flying Karamazov Brothers, a comic trio of jugglers, describe the differences between point source and nonpoint source pollution, and emphasize the importance of individual responsibility in the fourth video segment. The fifth presentation uses a teacher to lead into the school outreach program that features a call to action.

The Fantastic Journey, a 15-minute tape prepared by the City of Los Angeles, went behind the scenes with the video production crew to illustrate how stormwater pollutants travel through the storm drain system to the Santa Monica Bay. The video used the creative director of the City's 30-second PSA prepared for television to narrate this longer, more educational program. Visuals include the mountains of debris that accumulate in the Los Angeles storm drain system and end up on the beach. Viewers are shown various BMPs that the video production crew used to reduce their own contribution of pollutants (City of Los Angeles, 1994a).

Heal the Bay, an environmental organization based in Santa Monica, California, has produced several videotapes that have been shown on television and other forums. The latest is *Revenge*, which shows a car full of joyriders careening down a residential street, kicking grass and dirt onto private property, smashing into trash cans spreading litter everywhere, pouring oil on the ground, and even jumping out to light papers on fire on a doorstep. When the narrator asks if the audience would like this kind of treatment where they live, the camera pans to the joyriding occupants of the car: a dolphin and seals. The sound of the dolphin's call, which of course sounds like a cackling laugh, can be heard as the car drives away, and the narrator appeals to the audience to prevent pollution of storm drains (Heal the Bay, 1996).

5.3.5 Course Curricula

The Seattle Drainage and Wastewater Utility offered important insight (Seattle Drainage and Wastewater, 1996):

> "Meetings with Seattle middle school teachers were surprising. Teachers were quite blunt in saying they did not want or need more curriculum. There is more curriculum available than teachers know what to do with. Instead, new teaching tools are needed that can be integrated into the curriculum already being taught. It is important that the tools are flexible so that different teachers can use them in different ways."

With this in mind, a program was prepared with a teacher's manual, field trip directory, and resource guide. The teacher's manual includes activities and questions that correlate with the video "Water You Doing?" described earlier. The classroom can focus on the material for as little as one day and as many as five. Selected field trips are fully funded, including transportation, by the City of Seattle. The resource guide for teachers lists education centers, written materials, activities and lesson materials, audio/visual resources, and speakers willing to talk with classrooms of students.

The Central Contra Costa Sanitary District conducts school education using field trips to the wastewater treatment plant and in the third and fourth grade classrooms. The learning activities for the 3,000 3rd and 4th graders include pre-field trip materials and video, an activity folder, poster board and display board activities, and take-home materials (CCCSD, 1994).

The Center for Watershed Protection prepared a teacher's guide for creating a water monitoring program. Teachers of middle school students (10 to 14 years old) are provided with information, activities, and resources to create a unit about streams in the neighborhood. The class will adopt a segment of a stream, develop a monitoring program, and conduct field monitoring to study ecology. The guide points out that the class must have access to a stream. The guide teaches about watersheds, topographic maps, monitoring, and wild life (Center for Watershed Protection, no date).

EBMUD in Oakland, California, jointly with the California Water Pollution Control Association, Bay Section Public Education Committee, developed a science curriculum on wastewater treatment and pollution prevention issues for Roosevelt Junior High School in Oakland. EBMUD staff authored the chapters of the curriculum text, and the District provided funding for the project and tours of the main wastewater treatment plant for students (EBMUD, 1996).

5.3.6 Brochures, Pamphlets, and Other Written Materials

Several examples of effective messages have been included earlier in this chapter. There are many additional good themes and strategies for print materials as exemplified in the following paragraphs.

"Read this now. Or drink your old paint, chemicals, and pesticides later," a brochure by Metro Dade Solid Waste Management, Miami, Florida, reads in part. Having the reader's attention, the brochure tells how to safely manage chemicals, and provides several alternatives to toxic products. Clearly written information fits on a single 8 ½ x 11 page. Simple, but eye-catching, graphics deliver the message.

"What's Down That Dark Drain?" is a poster/publication produced just for kids by the Sacramento Stormwater Management Division. On one side, large text and simple graphics are used to tell children about storm drains and that nobody should pollute them with oil, litter, weed killers, and household toxics. The poster includes 10 different BMPs that children and their families can do. On the other side, there are several games and a simple test of knowledge.

Heal the Bay, an environmental organization in Santa Monica, California, produces several excellent print materials targeting the clean up of Santa Monica Bay. One of these is a fish-shaped door hanger that says "We're Healing the Bay One Neighborhood at a Time." The door hanger informs the reader that tens of millions of gallons of runoff daily end up in local coastal waters. Then the reader is invited to join in the stenciling program called the "Gutter Patrol." It includes a tear-off form to fill out with name and address in order to volunteer for the stenciling effort.

"Quick Guide to Car Care" for the do-it-yourselfer is a fan-style guide that informs people who maintain their own vehicles about ways to "help the car run better, save on fuel, prevent oil leaks, save on major repair costs, make your car safer to drive." The brochure also introduces "one more important benefit: good car care prevents water and air pollution." What is unique and especially effective about this item is its format. It is fashioned after the fans of paint or wood stain samples found in hardware stores: each page is 2" x 8" of laminated/heavy glossy paper; 12 pages are held together by a rivet that allows the user to fan to the selected "how-to" topic. It is convenient for do-it-yourselfers to keep by their side as they work on their cars, and because the paper is laminated, it is also easy to clean. This is prepared by CCSF and has been duplicated by other communities (CCSF, 1995b).

5.3.7 Advertisements, Promotional Items

Creative television ads and billboards can provide short, strong messages to the general public. For example:

Local cities and government agencies in King County, Washington, collaborated on a television ad that showed a man with a fertilizer spreader walking through the apparently shallow waters of Lake Sammammish. The words at the top of the screen said, "When you're fertilizing the lawn, remember you're not just fertilizing the lawn." This ad was part of a broader public education campaign focused on protection of the Lake Sammammish State Park.

The City of Los Angeles created a billboard that is a colorful, beautiful illustration showing the ocean full of marine creatures right below a city storm drain inlet. Text of the billboard states: "Storm drains lead directly to the ocean -- make the connection." This has been used on regular billboards, in bus stops, as posters and report covers.

Several communities have developed promotional items with stormwater or wastewater themes. The Riverside (California) Stormwater/Clean Water Protection Program has created a large plastic drawstring bag with storm drain illustrations and information on it, a visor, book cover, pencil, and smaller plastic garbage bags. Several communities produce refrigerator magnets with their logos or mascots. These magnets often encourage the reporting of storm drain violations. The City of Phoenix has post-it style note pads with the stormwater program telephone number and a cactus-shaped pencil. All of the promotional materials communicate the sponsor and the message to protect the environment in one form or another.

An interesting advertising strategy is used by the City of Phoenix. Callers who are put on hold when telephoning certain City departments listen to professionally produced pollution prevention tips (Louie, 1996).

5.4 Watershed Management/Stewardship Programs

Watershed management is becoming an important framework for environmental action in the '90s. People working together as stakeholders in a watershed are managing resources in a sustainable fashion. The concept of the approach is to build upon capabilities and overcome negative tendencies. In communities throughout the U.S., work is underway to bring different audiences together to work for the common goal of cleaner water. Some areas promote this as stewardship of a local water resource. Others promote the participation of stakeholders in a watershed management approach. Strategies promoting environmental stewardship include opportunities for training in grassroots fundraising, public speaking, legislative literacy, the policymaking process, and coalition building, as well as technical issues (Non-Point Source News Notes, 1995b). Other components of stewardship are cleanups of bodies of water and citizen monitoring. Examples of programs using the watershed approach are described below.

5.4.1 Lake Superior Binational Program

The States of Wisconsin, Minnesota, and Virginia and the province of Ontario, Canada, created the International Joint Commission (IJC) in 1989 to address boundary water quality issues (Larson et al., 1996). At the recommendation of the IJC, the Binational Program was launched to bring municipalities, native organizations, industries, environmental advocacy groups, academic community, and citizens together in forums to plan for a Lake Superior zero discharge demonstration program. Gradual pollutant reduction goals have been established by these stakeholders to achieve virtual elimination of pollutants by the year 2020.

5.4.2 National Cattlemen's Beef Association (NCBA) Water Quality Information Project

Beef cattle operations are commonly involved in forming partnerships in watershed management programs (Clawson, 1996). NCBA is also involved in forming partnerships at the State and national level among organizations and agencies. Cattle operators are concerned that they will lose control of their management operations. Crucial to successful watershed management efforts is recognition of property owners and their interests from the beginning, and not as an afterthought. The Water Quality Information Project started because of the lack of understanding of water quality assessment processes, potential impairments, and nonpoint source control programs. The project includes the NCBA Environmental Stewardship Award to winners in seven regions of the U.S.

5.4.3 The Rouge River National Wet Weather Demonstration Project

This project is an example of a watershed-based stormwater permitting process (Mercer, 1996). The river has been documented as a source of significant pollution to the Great Lakes system. The project developed a watershed-wide management program based upon the concept that each citizen has the right to expect clean water from their upstream neighbor and must extend the same courtesy to others downstream. A five-component strategy includes: 1) define working groups with a focused local purpose; 2) develop a common set of basic technical information; 3) identify and rank specific sub-watershed problems; 4) develop a long-term strategy and implementation process; and 5) allow for a watershed-wide NPDES permit or an alternative program.

5.4.4 St. Louis River Citizen Program

As part of a citizen monitoring program for the St. Louis River effort, students prepare slides of fish livers to assist US EPA in monitoring the condition of the environment. Residents count and identify frogs to track trends in the river's animal populations. Students also conducted a benthic macroinvertebrate study while others conduct water chemistry tests (Non-Point Source News Notes, 1994).

5.4.5 New York City Watershed Protection Program

An important element of a successful watershed management program is effectively representing the interests of all the stakeholders. Polarization had developed among stakeholders of New York City's watershed protection program to the extent that some stakeholders resorted to legal challenges (Stave, 1996). Participants viewed and valued watershed resources differently. Stakeholders included city water consumers, public agencies, farmers, tourism industry, and recreational users of the watershed. Understanding the basis for the differences was essential to bringing the stakeholders to some common ground. Closed door negotiations convened by New York's governor and lasting seven months initiated a resolution to the stakeholders' conflicts.

5.4.6 King County Department of Natural Resources

Another good example of the stewardship effort is described in the "1996 Community Stewardship Network Directory" distributed by the King County Department of Natural Resources, Seattle, Washington. It opens thus:

> "What you hold in your hands is a comprehensive directory of community and non-profit groups, government agencies and businesses involved in restoring and protecting the watersheds of King and other Puget Sound counties. This book will help you make new friends, seek assistance from government and business, and get connected with efforts to keep our local waters clean."

5.4.7 Puget Sound Water Quality Authority (PSWQA)

Beginning in 1987, the PSWQA entered into contracts with local groups for projects that solved local/regional environmental problems (PSWQA, 1993). The philosophy of this program is described by the following statement:

> "The watershed perspective offers another way of thinking, seeing, sharing responsibility and acting. The watershed is the big picture, comprised of an infinite number of smaller pictures. By seeing ourselves in the smaller picture, we can form the mosaic of the whole watershed and the roles and places of others.
>
> Watershed thinking requires new tools. Maps that answer questions like: What are our watershed's boundaries? Where does the water come from? Where does it go? Experiences like field trips that reacquaint us with our neighborhoods -- from a stream, storm drain, or sewer point of view.... Watershed thinking helps us sort big water quality problems into little ones -- the kind we can fix" (PSWQA, 1993).

The grant program enables various stakeholders to follow through with their smaller picture projects to address water quality concerns in the watershed. The program identifies key audiences as youth, homeowners, business, government, schools, nonprofit organizations, and Indian tribes.

Additional sources of information about watershed management programs include:

- Watershed '96: Moving Ahead Together, Preconference Workshop--Building a successful watershed framework, Clayton Creager, The Cadmus Group (workshop facilitator)
- The Rouge Project Catalog of Watershed Management Information, Rouge Program Office, 1996
- Lake Leelanau Landowner's Handbook, Our Lake, Our Responsibility, Fen's Rim Publications and South Lake Leelanau Steering Committee, no date
- Watershed Management Kit In a Box, Know Your Watershed - Conservation Technology Information Center, 1996.

5.5 Social Marketing/Behavior Change Principles

Environmental educators in some of the larger metropolitan areas are beginning to explore social marketing techniques to change the behavior of the public o stormwater issues, which is much more than simply increasing awareness. Social marketing is the process of selling behavioral change. Research is always used to help establish the educational strategies, much like the extensive research and tests that are conducted for product marketing before new items are offered and advertised for sale. Examples of programs that use social marketing strategies are anti-tobacco campaigns, AIDS awareness, and ride-share programs.

The anti-tobacco campaign offers an excellent illustration of how social marketing combines psychology, research, and public relations. Research showed that although smokers were well aware that they risked illness and death due to their habits, they still wouldn't quit. So a strategy was developed to attack the problem through public concerns for second-hand smoke because, while smokers were not willing to quit for their own health, many would quit if it would protect their spouses and/or children.

The Local Hazardous Waste Management Program in King County, Washington, researched behavior change literature from energy conservation, recycling, health education, and other fields (Frahm, 1996). The King County research found that information alone is not enough to change behavior. Developing a brochure providing the correct information will not, by itself, achieve the desired result. There are many barriers to achieving change besides lack of information. The recommended approach is to start a project by clearly defining the final objective, clearly identifying and understanding the audience, and addressing this audience's barriers to changing behavior.

Certain strategies effectively changed behavior. Insights from the King County research regarding these strategies are described.

Getting involved is the first step to making a commitment, and making a commitment makes people more likely to act. Small commitments lead to big ones. Start by getting the shop owner or resident involved in a visit. Then ask them to sign a form stating changes they will make. A study on improving recycling behavior asked residents to commit themselves to one, two, or three minor actions: complete a survey, save cans for a week, or send a postcard to the city council urging an increased recycling program. As the number of requested commitments increased, so did the recycling behavior. The effects were still observed 10 months later.

Feedback and follow-up are important. Feedback gives people cues about the impacts of their behavior changes. Additional contact is also very important in motivating people. Specific feedback (e.g., energy usage from hot water or turning on lights) and follow-up phone calls reminding people of a commitment are effective. In addition, comparative or social feedback appears to be useful. A large sign was posted alongside an expressway exit showing the percentage of drivers who were not speeding on the previous day. The sign reduced the number of speeding drivers by more than 50%. The same sign without any information about prior compliance had no effect.

People will listen first to their friends or relatives, or others they see as credible. What they hear at a dinner party often has more weight than a comprehensive data summary. Therefore, work through existing, trusted organizations; create a new, unbiased organization; share personal success stories; and arrange for people to meet those doing the desired behavior. One study found that farmers would not adopt a new hybrid seed corn, despite positive data from the U.S. Department of Agriculture, until one or two farmers who had tried the seed confirmed its value.

Change agents and role models are important. A few people in a group will typically adopt innovative ideas and behaviors first and spread them through the group. Find these people and help them successfully adopt a new behavior. The King County sewer utility works with farmers, often in rural areas far from the urban Seattle, to spread biosolids on their fields. Experience showed that reluctance to use urban biosolids was high until a local farmer would agree to provide a test site. The other farmers can see the results and talk with the local farmer and local extension agent about the benefits. This approach has been so successful that demand for King County's biosolids now far exceeds the available supply.

Changing attitudes may not change behavior. There is no strong direct or consistent relationship between attitudes and subsequent action. While 85% of respondents to a survey saw the energy crisis as serious, there was no clear relationship between energy related attitudes and conservation behavior. People who cited conservation as the most important strategy for improving our energy future were no more likely than others to take energy conservation actions.

Incentives may help change short-term, but probably not long term behavior. Incentives may be less effective at changing behavior than strategies that encourage people to internalize a behavior, such as commitment, norms or social recognition. People often respond to incentives by changing their behavior; but when the reward is removed, they generally revert to their original behavior. Researchers at an industrial complex gave drivers flyers that prompted seat belt usage and gave belt wearers the opportunity to win prizes. Seat belt usage increased in the afternoon when incentives were offered in the morning. However, after the incentives were withdrawn, belt usage returned to baseline levels.

If you need to provide information, present it effectively. People are more likely to pay attention to information that is vivid, personal, specific and concrete, stated in terms of loss rather than gain, told as a story, and emotional. Energy auditors used these concepts with good results. One study trained auditors to communicate vividly, personalize their recommendations, get homeowners involved in the audit to encourage commitment, and frame information in terms of loss instead of gain. The trained auditors had much greater success in getting people to follow through on their recommendations than did auditors without similar training.

CHAPTER 6.0

PROGRAM EFFECTIVENESS

Evaluating the effectiveness of pollution prevention, stormwater, and public education programs is critical to the success of source reduction efforts. Programs around the country seek tools to measure the effectiveness of their efforts. While it is crucially important, it is also a daunting and elusive task.

Despite the need to measure program effectiveness, to date, limited information is available in this area. Programs have not consistently incorporated evaluation into standard procedures for several reasons: a lack of adequate environmental data, scant developed performance measures, dearth of baseline information, and shortage of program evaluation tools. Evaluation procedures must be incorporated at the beginning of a project rather than tacked onto the end. This would allow the development of baseline information from which changes can be measured. In turn, environmental data or other performance measures must be available to develop good baseline information.

Most of the effectiveness measures reviewed for this project were based on water quality evaluations and public awareness surveys. In addition, there is an emerging interest in determining the effectiveness of programs based upon environmental indicators, such as those described in Chapter 2.0. Pollutant load reductions and water quality improvements are used by some programs to evaluate program effectiveness. Other environmental indicators that are used to measure effectiveness in studies reviewed herein include sediment quality and fish tissue analysis in the Chesapeake Bay and biosolids concentrations in the San Francisco Bay Area. Other effectiveness gauges are increased opportunities to reuse and reclaim effluent and biosolids, protection of worker health and safety, protection of operations at POTWs, and financial value/return on investment of pollution prevention equipment. Table 6–1 summarizes the measures of effectiveness for programs reviewed for this report.

Table 6-1. Examples of Program Effectiveness of Local Source Control Programs

Program/Municipality	Chapter Reference	Measure of Program Effectiveness
Palo Alto RWQCP (CA)	6.0	Pollutant loading reductions
East Bay Municipal Utility District (CA)	6.0	Pollutant loading reductions
Novato Sanitary District (CA)	6.0	Pollutant load reductions
Greenville (TX)	6.0	Decreased effluent toxicity Pollutant load reductions
New York/New Jersey Harbor	2.0	Ambient water quality conditions Fish tissue analysis Toxicity tests
Chesapeake Bay	2.0	Ambient water quality conditions Sediment quality Fish tissue analysis
City and County of San Francisco	2.0	Pollutant load reductions Biosolids concentration
Santa Monica Bay	2.0	Ambient water quality conditions Sediment quality Condition of habitat Potential health risk to swimmers Levels of contamination in shellfish
Erie County, New York	6.0	Value/return on investment in pollution prevention equipment

Efforts to evaluate program effectiveness based on the use of water quality and other indicators, development of models, and use of surveys are discussed below.

6.1 Program Evaluation Using Various Indicators

The ultimate goal of stormwater and wastewater pollution prevention programs is to reduce effluent loadings and improve water quality. However, using water quality to indicate program effectiveness is not always possible. It is difficult to see measurable differences in water quality when dealing with diffuse sources such as small businesses and homeowners. Reductions in effluent loadings or improvements in water quality can be observed when a specific pollutant issue can be traced to an individual source.

Pollutant load reductions have been indicators of program effectiveness with respect to vehicle service facilities, photoprocessing, corrosion, and pesticide use. Financial evaluation is another method of measuring program effectiveness.

6.1.1 Vehicle Service Facilities

The Palo Alto RWQCB and East Bay Municipal Utility District (EBMUD) each documented reductions in metals influent loading after the implementation of their vehicle service programs.

Of the 300 businesses in Palo Alto RWQCB's Vehicle Services Facilities Program, 65 are permitted for discharge while the remaining 235 facilities are zero dischargers. Based on sampling conducted by the Plant and the businesses, the Palo Alto RWQCB estimated that the 65 dischargers contributed 268 pounds of copper to the plant influent in 1993 (the first full year of the program). In 1994, sampling results indicated that the copper contribution from these facilities had dropped to 92 pounds (Louie, 1995).

EBMUD implemented its vehicle service program in 1992 issuing 251 permits to auto repair shops, fleets, and dealerships (EBMUD, 1996). Baseline levels of plant influent loadings were measured in 1988 for several pollutants, including cadmium, copper, lead, nickel, and zinc. Influent levels for these metals in 1993 (after program implementation) were substantially reduced. Copper levels went from 28 kg/day in 1988 to 20 kg/day in 1993. Cadmium levels were reduced to 0.6 kg/day in 1993 from 1.1 kg/day in 1988. Reductions in lead, nickel, and zinc between 1988 and 1996 were 76%, 51%, and 55%, respectively.

6.1.2 Photoprocessing

Prohibiting silver discharges from photoprocessors has effectively reduced silver levels in wastewater. Palo Alto RWQCB instituted its silver program in 1992 (PARWQCP, 1994b). Source identification studies determined that over 75% of the Palo Alto RWQCB's influent silver originated from approximately 350 relatively small commercial businesses. Palo Alto's sewer ordinance required these facilities to either haul spent fixer off-site for recycling or to recover the silver on-site and obtain a permit for the discharge of treated water to the sanitary sewer.

Due to this silver program, silver concentrations discharged to the San Francisco Bay by the Palo Alto RWQCB decreased from 14 μg/L in 1989 to 0.6 μg/L in 1993.

6.1.3 Corrosion

Novato Sanitary District was able to reduce its copper effluent loadings by working with its water purveyor, Sonoma County Water Agency (SCWA), to implement pH adjustment of the water supply. The water supply pH was approximately 7.5 prior to SCWA implementing corrosion control through pH adjustment in September of 1995. Adjustment of pH to 8.5 resulted in a dramatic reduction in copper loadings. Influent copper loadings were reduced by 55% with influent copper concentration decreasing from 140 μg/L prior to pH control in 1995 to 57 μmg/L in 1996. Effluent copper loadings decreased from an average of 29 μg/L in 1995 to 12 μg/L in 1996.

6.1.4 Pesticide Use

The City of Greenville, Texas, has a population of 23,000 and an average dry weather flow at its treatment plant of 3 Mgal/day (Erwin, 1996). In 1991 and 1992, the plant effluent failed 6 out of 7, and 11 out of 12 toxicity tests, respectively. Diazinon was identified as the cause of the toxicity, and monitoring indicated the diazinon was probably coming from residential sources. Diazinon levels ranged from 0.1 to 0.2 μg/L.

In late 1992, Greenville implemented a public education program. The program discouraged residents from using diazinon, encouraged the use of IPM practices, and recommended alternatives to pouring diazinon or even rinse water down the drain. Outreach methods included highway billboards, radio public service announcements, newspaper articles, school programs, and speakers for community groups.

Since 1993, Greenville has conducted toxicity testing monthly in the summer and quarterly in the winter. Toxicity failure has occurred no more than once per year from 1993 to 1995, with no toxicity failures through the middle of 1996. Since the public education program was implemented, diazinon levels in the City's effluent are primarily below the detection limit of 0.1 μg/L.

6.1.5 Financial Program Evaluation

The Department of Environment and Planning, Erie County, New York, evaluated the effectiveness of a pollution prevention program conducted by the Erie County Office of Pollution Prevention (Malcolm Pirnie, Inc., 1993). The program targeted small businesses and used a newsletter, conferences and presentations, site visits and follow-up reports, and an industrial advisory committee/focus group as primary methods of communication.

The evaluation process included reviewing materials and reports, contacting small businesses that had participated in the program, and a telephone survey. Results were compared to recommendations proposed by the Northeast Waste Management Officials Association and the National Roundtable of State Pollution Prevention Programs for evaluation of such efforts. The overall conclusions were that the program was valuable to its clients, did a good job of promoting awareness, and that the next step was to achieve measurable waste reduction. One-on-one site visits were perceived as the most successful element of the outreach program. The most prevalent barrier to implementation of pollution prevention measures was the cost of equipment. The evaluation report for the program recommended developing a case log of projects, particularly the financial aspects, to show small businesses the value and return of investing in pollution prevention (Malcolm Pirnie, Inc., 1993).

The Erie County evaluation report demonstrates that there are measures of performance other than water quality and awareness. In this case, the report stated that the documentation of financial value/return of investment in pollution prevention (case studies) is one important indicator of program effectiveness.

6.2 Using Models to Predict Effectiveness

Data can be compiled and used to develop models to predict program effectiveness. Two models, one based on demographic data and one based on water quality data, are described in this section.

The University of California at Berkeley, Department of Agricultural and Resource Economics, conducted an interesting study with a predictability model to correlate yard ownership and the use of chemicals associated with landscaping with residential socio-demographics (Templeton, 1996). There is widespread evidence of pesticides in creeks and other surface waters throughout the San Francisco Bay Area. Yet, based upon several factors, the study determined that up to

55.5% of San Francisco Bay Area households were using and/or disposing of pesticides in a manner that might make the quality of groundwater, surface runoff, and soil worse than it is. People were found to be primarily concerned with the appearance of their yard, and less concerned with underlying biological and physical processes associated with their landscaping. Choices related to pesticide use were also determined by constraints on information, time, and money (e.g., people generally did not take the time to read labels or disposal instructions.)

Conclusions of the study of the association of environmental behaviors with demographics include: the demands for yards and yard chemicals increase with family income; the impact of children on the use of chemicals depends upon how vulnerable to exposure they are and how able they are to help with yard maintenance; among those who keep yards, ownership (vs. renting) does not affect decisions related to chemical use. The authors noted that the predictability model would be of value to policy makers who regulate the use of yard chemicals and to sellers of pesticides and fertilizers as a marketing tool.

The County and City of Sacramento and Cities of Folsom and Galt developed a model to predict stormwater program effectiveness (LWA, 1996d). They jointly developed an analysis technique using specific statistics and modeling to assess trends and long-term effectiveness of the Sacramento Comprehensive Stormwater Management Program. The database was compiled from samples collected at three urban runoff monitoring locations during eleven storm events. The constituents included in the analysis were As, Cd, Cr, Cu, Fe, Pb, Zn, NH_3, BOD, coliform bacteria, hardness, nitrate and nitrite, oil and grease, phosphorus, organic carbon, TDS, TSS, and cyanide. The mathematical model predicted changes in stormwater quality as a result of program implementation ranging from 15% to 40% over a 20-year period.

6.3 Surveys

The effectiveness of public education programs is measured in different ways—improvements in water quality, number of calls received, number of participants in workshops and events. However, the most commonly used method of measurement with respect to public education is the survey. In this section are discussed surveys that have been used to measure general awareness and campaign effectiveness with respect to stormwater and wastewater pollution prevention issues. Table 6-2 lists the surveys reviewed for this project. (No surveys were reviewed that addressed either water quality evaluations or the cost effectiveness of a program.)

Table 6-2. Public Education Surveys

Agency	Survey Background	Summary of Findings
Chesapeake Bay Program University of Maryland 1994	Attitudes survey of awareness. Telephone survey of 2,004 residents in watershed.	85% of respondents are concerned about water pollution; 1/3 attribute pollutants to businesses. Only 7% thought individuals caused water pollution. Half of the respondents thought cleanup of Chesapeake Bay is very important. Opinions differed widely on how best to spend funds for Bay cleanup (e.g., funding for prevention vs. restoration).
Milwaukee River Program 1989	General awareness of stormwater issues, habits, and willingness to pay more to achieve water quality goals. Multi-page questionnaire mailed to 5,500 residents.	Public learns about environmental issues through media and other passive methods. Respondents do take actions to prevent pollution. They are willing to pay $50 to $75 per month to achieve goals.
City of Oklahoma, Oklahoma 1995	Survey of best management practices for pesticide use. Mailed survey to 17,000 residents. 3,002 were returned.	40% of the population do not use pesticides at all. Diazinon is a pollutant of concern causing toxicity for two of the City's treatment plants. The survey confirmed that residents in the service areas of these two plants use more diazinon products than other parts of the city.
Colorado Pollution Prevention Partnership 1994	Survey included in paper presented at Water Environment Federation annual conference. Telephone survey of 300 small and medium-sized (fewer than 500 employees) businesses across Colorado.	Conclusions were presented in text, not statistics. Businesses were found to comprehend what pollution prevention means, have implemented pollution-reduction practices, and consider suppliers to be among the most knowledgeable sources of information. Cost and economics were mentioned both as a barrier to pollution prevention and an incentive to increase the efforts of businesses.
Central Contra Costa County Sanitary District 1994	General awareness survey of water pollution causes and prevention. Telephone survey of 304 residents in ten cities.	83% were concerned about water pollution (top 2 or 3 environmental issues). Over half recognized that pollutants to storm and household drains are a major source of pollution.
Alameda Countywide Clean Water Program 1994	Survey of effectiveness of billboard campaign. Telephone survey of 300 county residents.	Billboards increased awareness of stormwater issues by 36%. 29% of respondents stated that they had changed their behavior as a result of the billboard campaign.

Table 6-2, cont. Public Education Surveys

Agency	Survey Background	Summary of Findings
Alameda Countywide Clean Water Program 1996	Survey of awareness of yard chemical use. Telephone survey of 1,200 county residents; conducted in English and Spanish.	More than one in three chemical users indicated that they followed proper use and disposal practices and that runoff from their property could safely go directly into the storm drains. Residents indicated that they would be willing to make additional behavioral changes as long as they were minor and convenient.
Santa Clara Valley Nonpoint Source Pollutant Control Program 1996	General awareness survey of urban runoff issues. Telephone survey of 1,200 valley residents.	58% said that pollution of the environment was very serious compared to 58% who considered traffic congestion as very serious. The majority believed that trash in streets, improper disposal of household hazardous wastes, and oil leaking from cars caused pollution in San Francisco Bay.
Los Angeles County Department of Public Works 1996	General awareness of do-it-yourselfers' 16 years and older. Telephone survey of 2,003 county residents.	Oil changers are predominantly male, largely from African American and Latino heritage, and frequently use Spanish as their primary language. Pesticide and fertilizer users tend to be largely from the English-speaking, non-Latino population over 45. 83% of do-it-yourselfers recycle aluminum cans; 74% recycle plastic bottles. The survey recommended a multi-media (newspaper and radio) campaign along with point-of-purchase outreach.
Los Angeles County Department of Public Works 1995	General awareness of storm drain system and background information to target audiences for public education campaign. Telephone survey of 2,400 adult residents in Los Angeles County.	Pollution of waterways is a major concern, but not at the same level as crime related issues. 88% believe waterways are polluted. 71% believe groundwater is polluted and half drink bottled water. Less than 25% had seen, heard, or ready anything about storm drains. Broadcast t.v. and newspapers were top two sources of information about stormwater.
City and County of San Francisco 1992	General awareness survey of best management practices. Telephone survey of 2,801 residents.	Majority of respondents blame businesses and industry for water pollution. 41% of households get information about environmental issues from newspapers. More than 2 out of 5 people associated great health risks with solvents, drain cleaners, and pesticides. The most commonly used toxic materials were nail polish removers (51%), motor oil (47%), and house paint (42%).

Table 6-2, cont. Public Education Surveys

Agency	Survey Background	Summary of Findings
City and County of San Francisco 1994	Survey of households -- use and safe disposal of household toxic products. Telephone survey of 1,886 households.	Respondents indicated a high level of awareness of environmental issues. Compared to 1992 survey, there was an increase in awareness that households are a major source of water pollution. 33% saw public education campaign signs.
City and County of San Francisco 1996	Survey of effectiveness of Clean It! campaign. Bi-annual telephone survey of 401 residents.	15% of respondents were aware of campaign; 11% recalled the message. Street sign ads and utility bill inserts were the most effective information sources.
City and County of San Francisco 1996	Survey of effectiveness of Clean It! and The Less Toxic Garden campaigns. Survey mailed with Water Warriors! City newsletter.	Data compilation underway.
City of Seattle Solid Waste Utility by the Seattle Tilth Association 1993	Final evaluation report of Green Gardening Program. Follow-up telephone survey of participants in Green Gardening educational events.	65% of participants used pesticides of which 11% used them regularly. 68% said that they had not taken steps to reduce the use of chemicals but 88% said they planned to try some techniques they learned in the workshops in the future. 45% of participants learned something about compost use and 85% would be very likely to attend a more detailed future workshop.
U.S. Environmental Protection Agency, Region 10 1994	Study of 12 nonpoint source public education programs, including survey techniques.	Cited among the more effective outreach techniques are peer-to-peer education, financial incentives, mobile signage posting BMPs, and newsletters.
U.S. Environmental Protection Agency, Region 3 undated	Manual on measuring effectiveness of state pollution prevention programs.	Compilation of methods, questionnaires, and surveys used by various projects to measure effectiveness of waste and pollution prevention programs.

Surveys are conducted by trained researchers, not amateurs. They are carefully designed to measure different things: public awareness and habits; success of a particular campaign; an evaluation of water quality; and cost effectiveness/analysis of source control strategies and outreach efforts. Typically, survey questions are asked in telephone interviews with a randomly selected audience or in questionnaires mailed to a particular group by zip code, newsletter mailing list, or a business association. Results are carefully summarized and reported to the sponsoring agency. In some cases, the research company interprets the results and/or recommendations.

6.3.1 General Awareness Surveys

Surveys of public awareness are used to determine how well public education programs are working and how public education programs should be focused to produce the most impact. Of the ten surveys of general awareness of stormwater and pollution prevention issues reviewed, there was only one set of "before-and-after" questionnaires for a specific public education program that allowed a comparison of results. CCSF conducted awareness surveys in 1992 and 1994 and found that within those two years, a larger percentage of the public had come to realize that households were a major source of water pollution (CCSF, 1994). The survey summary comparisons also indicated the following:

- "Use: Overall levels of household use of toxic products were about the same in 1994 as in 1992, except that the rate of the use of motor oil and antifreeze declined significantly during this period.

- Unsafe Disposal Practices (UDP): Where comparisons could be made for specific products, the rates of unsafe disposal of toxics down street or house drains were about the same in 1994 as in 1992. The UDP rate (all toxic products combined) increased from an estimated 3.49% in 1992 to 6.32% in 1994.

- Support for increased local government efforts to improve water quality and to educate the public. Household residents continue overwhelmingly to support increased efforts by CCSF to improve water quality and to educate the public about toxics and their safe disposal. The level of support was about as high in 1994 as it was in 1992, and that strong support is found in all areas of the city and in all demographic groups."

The survey shows that the public education program is working and producing results within two years. During the period between 1992 and 1994, CCSF conducted at least three major public education campaigns that targeted the general public and pollutants associated with household maintenance (Clean It!), gardening (The Less Toxic Garden) and used motor oil recycling. Household hazardous waste facilities were publicized. Workshops, utility bill inserts, newsletters, public events, and using the media were all part of the public education program to deal with the issue of San Francisco Bay pollution (CCSF, 1996).

The surveys of other programs included results that would help target public education efforts. Examples of survey results that lead to a targeted program are:

- The Milwaukee River Program learned that the media best provide environmental information to residents. In fact, through the survey, the program learned that the traditional methods used by agencies (meetings, brochures, fact sheets) are rejected by most people in the lower Milwaukee River basin. Watershed practitioners were encouraged to increase their access and use of local television, newspapers, and other media in their outreach campaigns (Simpson, 1994).

- The City of Oklahoma City concluded from its survey that a public education program that targets the general public audience would be the most effective plan for addressing the City's toxicity problems. The program would also educate specific user groups. A two-year plan was developed to inform the public about the proper usage of pesticides. Many decisions in the public education program were made based upon survey results (APA, 1995).

- The survey conducted for the Los Angeles County Department of Public Works recommended that the agency focus media dollars on a campaign that combines point-of-purchase and radio advertising efforts. The survey also indicated that do-it-yourselfers frequent only a few retail stores. Therefore, a public-private partnership developed with those retail stores to educate do-it-yourselfers on environmental issues has a good chance for success (LA County, Department of Public Works, 1996).

6.3.2 Surveys that Measure Effectiveness of Campaigns

There is tremendous creativity in public education concerning environmental issues. Agencies have developed campaigns that feature billboards, points-of-purchase efforts, radio and television

PSAs, series of workshops, and many print materials. Surveys have been conducted on several of these specific campaigns to determine whether or not a single approach (e.g. billboard) changed the public's level of awareness or behavior.

The Alameda Countywide Clean Water Program reported the results of pre- and post-advertising surveys conducted in 1994 regarding an advertising campaign that featured billboards, newspaper ads, and busboards on county transit buses. The outdoor billboards showed a couple running through fuscia-colored water discussing the effects of pouring paint in storm drains. The overall campaign showed snapshots of residents unknowingly "planning" to pollute the bay by various activities, such as dumping paint and oil in their nearby storm drain.

Telephone surveys of 300 residents indicated a pre- and post-advertising awareness of the issues of 46% and 70%, respectively. Furthermore, the post-advertising survey showed that more than 40% of the respondents stated they were more careful in handling pollutants.

According to Sharon Gosselin, the public information/participation coordinator of Alameda County's program, "It (the survey) also suggested that the next stage of communication efforts should focus more on the indirect ways that contaminants enter the storm drain as well as continue to promote alternatives to polluting and alternative behaviors and disposal methods. The post-advertising campaign survey validates this approach" (Alameda County, no date, Pure Water).

The survey that evaluated the City and County of San Francisco's **Clean It!** campaign yielded a great deal of information about the numbers of people who learned something about safer housecleaning, including:

- Of the respondents who stated that they learned something related to the campaign, 51% got their information solely from street signs. This meant that if street signs had not been part of the overall strategy, between 11,285 and 25,925 households would not have gotten the message.

- "Vinegar makes windows sparkle" was a campaign message that motivated 2.7% of the population to use vinegar instead of toxic cleaning products. This accounts for between 4,270 and 14,845 households citywide (CCSF, 1996).

CHAPTER 7.0

SUMMARY AND RECOMMENDATIONS

This chapter presents (1) the summary of project findings; and (2) recommendations for future research to address information gaps regarding stormwater and wastewater pollution prevention programs targeting commercial and residential sources.

7.1 Summary

Project results with respect to monitoring and source identification, commercial sources of pollutants, residential sources of pollutants, public education programs and program effectiveness are summarized in the following subsections.

7.1.1 Monitoring and Source Identification

Forty-eight monitoring studies conducted to identify wastewater and stormwater pollutants and their sources were reviewed (see Chapter 2.0). While this was by no means an exhaustive review, the results are representative of the current status of pollutant and source identification efforts for wastewater and stormwater. The pollutants evaluated in these studies are listed in Table 7-1.

Metals were the most commonly evaluated group of pollutants, with 36 of the 48 studies addressing metals. Metals studies have been conducted for both stormwater and wastewater. Metals that have commonly been measured at levels of concern include copper, mercury, nickel, lead and zinc.

Pesticides appear to be an area of emerging interest and recent activity. Fourteen of the studies evaluated pesticides or their sources for stormwater and/or wastewater. Organophosphate pesticides (e.g., chlorpyrifos and diazinon) are of particular concern because they have been linked to discharge and receiving water toxicity in many parts of the country.

Table 7-1. Summary of Pollutants Evaluated
(out of 48 studies)

Category	Number of Studies	Pollutants Most Commonly Evaluated
Metals	36	Cu, Hg, Ni, Pb, Zn
Pesticides	14	chlorpyrifos, diazinon
Organics	13	PAHs, solvents, hydrocarbons
Nutrients	10	phosphorus, ammonia
Conventional	9	BOD, TSS, oil and grease
Others	5	cyanide, tributyltin

A number of studies identified other organic pollutants at levels that have the potential to be of concern to wastewater or stormwater. These pollutants include bis-(2-ethylhexyl)phthalate, dioxins, PCBs, and PAHs. Solvents and hydrocarbons were also evaluated in some of these studies. Despite the number of monitoring studies that have addressed organic pollutants, the data are limited by the high cost of conducting laboratory analyses for many of these compounds and because, for a number of these pollutants, the analytical detection limits are higher than water quality standards. This makes it difficult to determine if many organic pollutants are present at levels of concern.

Numerous studies (19) evaluated levels of conventional pollutants and nutrients. Most of these studies addressed stormwater. Much of the effort regarding nutrients has been conducted on the East Coast, particularly in the Chesapeake Bay Area.

With respect to source identification, several studies evaluated wastewater or runoff from commercial or residential areas. Few of these studies have sought to identify specific sources (e.g., individual businesses, specific residential activities) within the commercial or residential area. In addition, little work has been done to identify the pathways that transport the pollutants of concern from commercial or residential sources to wastewater or stormwater.

In general, studies that have investigated specific commercial businesses or residential activities have done this by evaluating operations and materials used rather than through wastewater or runoff sampling. Some exceptions are the Central Contra Costa Sanitary District residential metals study and investigations of auto-recyclers described in Chapters 3.0 and 4.0. It is often difficult to obtain representative wastewater or runoff samples from small businesses or residential sources.

7.1.2 Commercial Sources of Pollutants

Several strategies have been developed to address commercial sources including permitting, educational outreach, recognition programs, and business assistance centers. These approaches have been well-developed throughout the country.

Commercial sources evaluated are listed in Table 7-2 along with the number of programs which evaluated each source. While this is not an exhaustive list of every program working with commercial sources, it is believed to be representative of the current status with respect to evaluating and controlling commercial sources.

Many programs all over the country have developed source control programs for addressing vehicle service facilities, construction activities, and food service businesses. Reasons for this are that most communities have many businesses that fall into these categories and that these businesses are subject to multiple regulatory programs (e.g., wastewater, stormwater, air quality, hazardous materials, health services, etc.).

Source control programs have also been developed for printers, painting contractors, dentists, laboratories, medical facilities, photoprocessors, landscape maintenance, dry cleaners, and machine shops. It should be noted that some of the programs addressing printers, dry cleaners and machine shops focus more on air emissions and hazardous materials generation than wastewater or stormwater issues. In general, there appears to be considerable information regarding these sources.

Sources for which little work has been done include brake pads, existing development, wood finishers, jewelry manufacturers, mobile cleaners, cooling water systems, commercial pesticide users, new development, and ceramics studios. Of these sources, the following have the potential to have discharges containing pollutants at significant levels: brake pads, existing development, new development, mobile cleaners, and pesticide users. These sources may be effectively addressed through pollution prevention approaches.

Table 7-2. Pollutants Associated with Commercial Sources

Commercial Source	Wastewater or Stormwater	Associated Pollutants	Number of Programs	Number of Regions
Existing development	Stormwater	Metals, pesticides, nutrients, vehicle fluids	2	1
Brake pads	Stormwater	Copper, lead, zinc	3	1
Ceramics	Wastewater	Metals, solids	3	2
Wood finishers	Wastewater	Solvents, metals	4	3
Jewelry manufacturing	Wastewater	Silver, cyanide, copper	5	3
Landscape maintenance	Stormwater	Nutrients, pesticides	12	3
Mobile cleaners	Stormwater	Solvents, metals, oil & grease, detergents	6	3
Cooling water systems	Wastewater	Copper, tributyltin, zinc, lead	8	4
New development	Stormwater	Sediment, nutrients, pesticides, solvents, metals	9	4
Painting contractors	Both	Solvents, metals	10	5
Laboratories and medical facilities	Wastewater	Mercury, silver, selenium, copper, formaldehyde, phenolics, cyanide, solvents, xylenes, radioactive wastes	13	5
Boatyards/ marinas	Stormwater	Solvents, engine fluids, sewage	12	5
Dry cleaners	Wastewater	Perchloroethylene	17	5
Machine shops	Wastewater	Metals, oil & grease, solvents	16	5
Food service businesses	Both	Oil & grease	23	5
Dentists	Wastewater	Mercury, silver	14	6
Photoprocessors	Wastewater	Silver, selenium	18	7
Construction	Stormwater	Sediment, nutrients, pesticides, solvents, metals	28	8
Printers	Wastewater	Metals, solvents	26	9
Vehicle service facilities	Both	Metals, oil & grease, solvents, PAHs	45	10

No information was collected during this project regarding programs addressing over-the-counter products containing ingredients that result in wastewater or stormwater pollution. Little information appears to be available concerning this topic. Some examples of products containing ingredients of interest include pesticides (e.g., copper stabilizers in cooling water additives) and cleaning products (e.g., zinc in floor waxes, tributyltin in toilet bowl and carpet cleaners).

Such products typically do not provide a complete list of chemical contents, primarily because manufacturers consider the formulations proprietary. While the Material Safety Data Sheet (MSDS) must list human health hazards, listing of water pollutants is not required. Further, for pesticides, inert ingredients (e.g., copper stabilizers in cooling water additives) need not be disclosed on the label or MSDS. In most cases, even if the presence of a pollutant of interest is noted on product information, the concentration of the material is not specified. These conditions make identifying product related sources difficult and expensive.

7.1.3 Residential Sources of Pollutants

Several approaches are available to address residential sources of pollutants, including public education, legislative strategies, and technology-based strategies. The most commonly used approach for residential sources is public education. In many cases, technology-based strategies or legislative strategies are beyond the jurisdiction of local governments, and therefore, are rarely used to address residential sources. Exceptions include pH control of the water supply to address corrosion and the product restrictions for copper sulfate root control products enacted in the San Francisco Bay Area.

Residential sources that have been evaluated for this project are listed in Table 7-3. This list is representative of the current status of efforts nationwide regarding residential sources. As is shown in Table 7-3, most of the programs developed targeting residential sources focus on landscape maintenance or household cleaners. In most cases, landscape maintenance outreach targets general practices as opposed to specific products. With respect to household cleaners, much of the outreach targets products that have been determined to be of little concern to wastewater.

A moderate amount of work has been done to address water supply corrosion and home vehicle maintenance. Effective source control for corrosion has been to work with the water purveyors to reduce the corrosivity of the water supply. Little work has been done to address laundry graywater, pools and spas, painting activities, root control products or pet care. Laundry graywater appears to be a significant source of several metals in wastewater.

Table 7-3. Pollutants Associated with Residential Activities

Residential Source	Concern to Wastewater or Stormwater	Associated Pollutants	Number of Programs	Number of Regions
Pet care	Wastewater, Stormwater	pesticides (flea dips), animal wastes	4	3
Laundry graywater	Wastewater	heavy metals	5	2
Pools and spas	Stormwater, Wastewater	chlorine, copper	5	1
Painting activities	Stormwater	heavy metals, solvents	7	4
Indoor pest control	Wastewater	pesticides	10	6
Corrosion	Wastewater	Cu, Pb, Zn	11	6
Root control products	Wastewater	copper	12	2
Vehicle maintenance	Stormwater	oil, heavy metals	15	7
Household cleaners	Wastewater	solvents, ammonia, bleaches	20	9
Landscape maintenance	Stormwater	pesticides, nutrients	24	8

Painting activities do not appear to represent a substantial source of metals or other pollutants of concern. Pools and spas and root control products are associated primarily with copper. Pet care is likely to be a significant source of pesticides to wastewater.

Much of the work regarding residential sources of pollutants has focused on identifying these sources. Outreach targeting residential activities tends to be focus on creating general awareness rather than targeting specific activities. Where outreach is specific, programs appear to be effective. Some examples include programs targeting used motor oil and the Greenville, Texas, effort to eliminate wastewater toxicity by educating the public regarding diazinon. Focused outreach efforts such as these are few.

Another limitation regarding residential sources is that, once a pollutant's source is identified as residential, effective control strategies can be difficult to implement. Control of residential sources requires effective public education to reach the right audience and elicit behavior change. Some residential control strategies would require the use of an alternative consumer product. Both of these approaches are difficult to implement effectively.

7.1.4 Public Education Programs

There is an extensive effort throughout the country to educate the public on preventing stormwater and wastewater pollution. The messages communicated are fairly uniform from program to program. The general public and targeted audiences are being told what the environmental concerns are and what they as individuals can do about them. However, while the public is being given the same key messages, there is no uniform catch-phrase. By comparison, other environmentally-oriented programs, such as recycling and litter control, have phrases that are consistently used to reinforce the central message: The "Three Rs of Recycling: Reduce, Reuse, Recycle" and "Give a Hoot, Don't Pollute" are examples. From a marketing point of view, a consistent message would help stormwater and pollution prevention programs achieve stronger public recognition of the issues.

Approximately 30 of the 75 agencies providing public education materials for this project developed materials that communicate general messages to the general public. Approximately half of the 30 agencies augmented the general message materials with brochures, newsletters, guides, and other printed materials that targeted specific activities, such as vehicle and household maintenance and gardening.

With respect to educational materials that have been prepared for businesses (15 of 75 agencies), it would appear that a moderate level of progress has been made. Business coalitions have been formed, grant programs implemented, training sessions conducted, and print materials distributed. In addition to educational materials, there are numerous brochures defining best management practices (BMPs) for businesses. Combining educational outreach to businesses with the BMP materials that have been produced and distributed, indicates a substantial effort to educate the business community.

Twenty-three agencies provided materials that showed their efforts to provide water quality information to school-age children. School children are not a major source of pollution; however, they serve as role models, reinforce environmental messages within their households, and carry what they learn into future generations.

Of the other public education programs, 8 agencies targeted employees of government agencies for stormwater and pollution prevention education in order to set an example for others in the community.

Public education programs are also being developed to target ethnic segments of communities. Public service announcements and articles are prepared for radio stations and publications targeting specific communities. Some programs have also researched values and cultural issues specific to a given ethnic community and used this information to develop effective campaigns.

Watershed management is increasingly being used as a framework for environmental action. This approach attempts to bring stakeholders representing different interests to the table together, recognizing the contributions and issues of each party. The watershed/stewardship approach broadens the outlook of the various participants in that they are encouraged to understand each other's issues and concerns. There are a number of models to help stakeholders and the public learn about watersheds and the mix of issues that are involved in keeping waterways clean.

Gradual improvement in the effectiveness of public education programs is expected from the increased use of social marketing and behavioral change principles. Research in these areas indicates that providing information alone will not change behavior. The better approach involves identifying the desired outcome, identifying the appropriate audience, learning about that audience, and understanding its particular barriers to change. Methods have been developed to overcome these barriers in other fields (i.e., energy conservation and health care) that can be applied to wastewater and stormwater pollution prevention.

7.1.5 Program Effectiveness

While many agencies have indicated a need to evaluate the effectiveness of their programs, little information is available concerning available tools for measuring effectiveness. Some information is available on using water quality measurements and surveys as indicators of program effectiveness. Other indicators include increases in opportunities to reuse effluent and biosolids, protection of worker health and safety, protection of POTW operation, and financial value.

One obvious method of measuring program effectiveness is through improvements in water quality. There is very little information available on programs that have used this as an indicator of successful commercial and residential programs. When dealing with diffuse sources, such as small businesses or homeowners, it is difficult to see measurable differences in water quality as a result of pollution prevention efforts. Notable exceptions include:

- Reduction of silver levels in the Palo Alto treatment plant effluent attributed to a pollution prevention program directed at photoprocessors;
- Reduction in copper levels in Novato Sanitary District treatment effluent attributed to corrosion control measures; and
- Reduction in whole effluent toxicity in the Greenville treatment plant effluent attributed to a diazinon outreach program.

In each of these cases, a specific pollutant issue could be traced back to a specific commercial or residential activity. This suggests that to use water quality improvement as an effectiveness indicator, it may be necessary to conduct focused programs such as these.

Models can be developed to predict program effectiveness using baseline information. Two such models, one using demographic data and one using water quality data, are discussed in Chapter 6.0.

Surveys are another indicator used to measure the effectiveness of public education programs. Surveys help either validate that the educational efforts are working or that they need to be fine-tuned to become more effective. In addition, surveys have helped identify the most effective tools for communicating with the public (e.g., the media, utility bill inserts, and street signs).

7.1.5 Program Effectiveness

While many agencies have indicated a need to evaluate the effectiveness of their programs, little information is available concerning available tools for measuring effectiveness. Some information is available on using water quality measurements and surveys as indicators of program effectiveness. Other indicators include increases in opportunities to reuse effluent and biosolids, protection of worker health and safety, protection of POTW operation, and financial value.

One obvious method of measuring program effectiveness is through improvements in water quality. There is very little information available on programs that have used this as an indicator of successful commercial and residential programs. When dealing with diffuse sources, such as small businesses or homeowners, it is difficult to see measurable differences in water quality as a result of pollution prevention efforts. Notable exceptions include:

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solution might not be acceptable from a water quality retrospective. Successfully addressing these communication gaps between environmental programs is necessary.

In addition, it is becoming increasingly clear that a number of pollutants in stormwater and receiving water emanate from other media, such as airsheds above watersheds and groundwater basins near receiving water bodies. Airsheds have been identified as a significant contributor of nutrients to the Chesapeake Bay and acid rain to northeastern lakes. Pollutants, such as pesticides, dioxin, PAHs, and some heavy metals, also appear to be entering watersheds from the airsheds above them. Because environmental regulation in the U.S. is media-based, information on the existence, fate, and transport of pollutants from one medium to another is not necessarily covered by existing regulations and programs. A forum for communication between environmental programs would also help address this issue.

3. Conduct a monitoring program on non-stormwater discharges.

One of the two primary goals of the Federal stormwater regulations is to eliminate non-stormwater discharges to storm drain systems. However, very few data address the quality and quantity of the wide range of non-stormwater discharges (e.g., swimming pool discharges, vehicle washwater, pumped groundwater) present in most communities. This lack of data impedes the efforts of municipal stormwater programs to meet their Federal mandate. Representative monitoring data would allow stormwater management programs to focus their efforts on the non-stormwater discharges of most concern and facilitate the acceptance of these discharges by wastewater agencies.

4. Develop a wastewater/ stormwater pollution prevention information resource.

A mechanism for sharing information about water pollutant source control programs and public education materials should be created. This would allow agencies throughout the country to share information about pollutant sources and effective source control approaches. It would also allow public information materials already developed by others to be made available to all.

5. Develop tools to measure program effectiveness.

Very little information is available on the effectiveness of pollution prevention programs aimed at commercial and residential sources. Two factors contribute to this: (1) the difficulty of measuring the effectiveness of programs targeting such diverse sources; and (2) the unavailability of tools for this purpose. Research is needed to develop tools to measure the effectiveness of wastewater, stormwater, and public education programs. Measurements of effectiveness will help program managers focus their resources on the most effective control measures and improve the overall results of their efforts.

6. **Develop pollution prevention strategies for the following sources: automotive brake pads, pesticides, existing commercial development, mobile cleaners, laundry graywater, new development, and vehicle-related areas.**

These sources have been identified as potentially significant with respect to stormwater or wastewater pollution, but as yet, little work has addressed them. Effective reduction of the adverse water quality impacts from these sources requires future efforts to evaluate the sources and to develop effective control strategies as discussed in the following paragraphs.

Brake pads. As discussed in Chapter 3.0, automotive brake pads are a potentially significant source of copper. Research is needed to determine the fate and transport of copper from the brake pads to stormwater and then to surface water. The results of this research would help determine whether product modification would improve water quality. A voluntary partnership has been forged between local governments and industry to address these issues. The effectiveness of this partnership would be enhanced by national exposure and support of local governments nationwide.

Pesticides. There is increasing concern with pesticides in stormwater and wastewater. With respect to the water quality impacts of pesticides from these sources, there are three aspects of pesticides that could benefit from further research or program development.

First, there is a need to develop public outreach programs which target indoor pest control, pet care, and commercial users of pesticides (e.g., pest control operators, landscaping businesses, and small businesses with landscaping on-site). There has been a great deal of public outreach targeting use of pesticides for lawns and gardens, but little or none for these other potentially important uses.

Second, there is a need to develop outreach programs which target specific pesticides, rather than pesticides in general, where specific pesticides have been identified as sources of water quality impairment. It is increasingly common to find that specific pesticides are causing violation of water quality standards, in which case it is prudent to target those pesticides, rather than pesticides in general, for control.

Finally, there is a need for US EPA to investigate the feasibility of modifying its pesticides registration processes so that: (1) they consider potential water quality impacts resulting from pesticides in wastewater and stormwater; and (2) they consider inert, as well as active ingredients. US EPA's current pesticides registration processes require analysis of groundwater impacts for pesticides, but do not require the types of analysis necessary to determine whether the product could adversely impact surface waters through stormwater runoff or wastewater treatment plant discharges. In addition, US EPA's registration processes do not routinely consider the impacts of inert ingredients on surface water quality. In some cases, the inert ingredients (e.g., copper) can pose as great a water quality threat as the active ingredients.

Existing Commercial Development. Existing commercial development, such as office buildings, educational institutions, shopping malls, hotels and other buildings with a mix of business activities, can be a significant source of pollutants in wastewater and stormwater. Potential sources of wastewater or stormwater pollutants from such development include landscape maintenance, cooling water systems, food service operations, mechanical and auto repair facilities, parking lot cleaning, and other facility maintenance activities. Because of the variety of businesses involved, identifying and outreaching to this group is difficult. However, because of their potential contribution to wastewater and stormwater, programs need to be developed to identify and outreach to this group.

Mobile Cleaners. Surface cleaning operations, often performed by mobile cleaners, produce discharges that are of concern with respect to wastewater or stormwater, depending upon where the discharges are directed. The discharges contain both cleaning chemicals, such as soaps and solvents, and removed materials, such as oil and grease from parking lots and paint from building surfaces. Programs are needed to contact mobile cleaners, characterize their discharges, and develop effective pollution prevention programs. Mobile cleaners are challenging to identify and contact because they do not work at specific locations. The BASMAA pilot project described in Chapter 3.0 developed approaches to working with this group that might provide a successful model for other communities.

Laundry Graywater. Laundry graywater appears to be a significant source of several metals in wastewater. Control of this source would be either through the use of graywater systems or through the development and use of metal free dyes in clothing. Implementing either of these measures would be difficult at the local level. Use of graywater systems requires extensive public outreach and cooperation between the wastewater authority, building and planning departments, developers, landscape businesses, and plumbing unions. Development of metal-free dyes would require a national coalition of local governments and industry representatives. The effectiveness and feasibility of these potential control strategies needs to be investigated.

New Development. While BMPs related to construction activities are well developed, practices relating to planning and design of new development need to be evaluated. It might be feasible to lay out new development so as to reduce the potential for contaminating stormwater runoff. It might also be feasible to use building materials that would reduce the pollutants present in both wastewater and stormwater. For example, use of non-copper plumbing materials would reduce copper loadings in wastewater due to corrosion.

Vehicle Related Areas. Vehicles have been identified as a significant contributor of some of the most ubiquitous pollutants of concern in surface waters (e.g., oil and grease, PAHs, and heavy metals). A significant portion of these pollutants reach surface waters as a result of stormwater runoff from roads, bridges, parking areas, and driveways. These vehicle related areas take up considerable space in our communities, and in many cases, they are connected directly to storm drain systems. As a result, pollutants in runoff from these areas are transported directly to surface waters. Research is needed on how to reduce the pollutants in stormwater runoff from vehicle related areas.

7. Application of scientific principles to public education.

As evidenced by the results of this assessment, wastewater and stormwater agencies are beginning to use pollution prevention programs, as opposed to end-of-pipe treatment, to achieve additional pollutant reductions. Key to the success of these programs will be the ability of public education programs to bring about behavioral changes in society. Most public education programs aimed at reducing pollutant sources in wastewater and stormwater, however, are relatively unscientific. For public education programs to reach the majority of the population and effect behavioral changes, it will be necessary to incorporate psychological and marketing principles and techniques that have been successfully used in other fields. Research is needed as to how to apply these scientific principles and techniques to effect behavioral changes in the context of wastewater and stormwater pollution prevention programs.

8. **Produce a CD-ROM containing examples of public education materials.**

The project team collected many examples of public education materials directed at wastewater and stormwater programs. These materials could serve as a valuable resource to wastewater and stormwater agencies that are interested in developing new public education materials or in modifying existing materials. An efficient mechanism to make this material available to interested parties would be to place it on a CD-ROM. This would provide a single, easily accessible resource containing full color presentations of public education materials developed by others. The CD-ROM could be updated periodically and distributed through WERF. A catalog could accompany the CD-ROM.

9. **Develop a uniform catch phrase for wastewater and stormwater pollution prevention programs.**

Although there are numerous messages being communicated to the public with respect to wastewater and stormwater pollution prevention, there is no uniform catch-phrase or slogan (e.g., "Give a Hoot, Don't Pollute"). Efforts should be made to develop a uniform, nationwide catch-phrase for the wastewater and stormwater pollution prevention programs. This would result in stronger public recognition and thereby facilitate achievement of program goals.

10. **Focus pollution prevention strategies and public education materials on locally important pollutants of concern.**

Pollution prevention strategies and associated public educational materials have tended to be rather generic. They have typically focused on general pollutant classes (e.g., pesticides or motor oil) and/or specific pollutant sources (e.g., construction activities or vehicle repair facilities). Although it is desirable to reduce the discharge of all pollutants to all waters, the success of individual wastewater and stormwater pollution control programs will ultimately be judged on whether water quality standards are achieved. Local pollution prevention efforts, therefore, need to be focused more directly on the control of those pollutants which are responsible for exceedance of standards in local waters. This will involve: (1) identifying the pollutants which are responsible for violation of standards; (2) identifying possible community sources of those pollutants; (3) quantifying and prioritizing the sources; and (4) developing pollution prevention program to address the significant community sources of the pollutants of concern. Developing pollution prevention and public education programs in conjunction with the watershed approach should help focus these programs on locally important pollutants of concern.

7.2.2 Assigning Priorities to Workshop Recommendations

The findings of the project team and the resulting recommendations were presented at a workshop at WEFTEC '96 in Dallas, Texas, on October 5, 1996. The recommendations were discussed by the workshop participants, consolidated in some cases, and assigned priorities. The following recommendations were given the highest priority by the workshop participants:

1. **Develop and maintain a clearinghouse or information resource on wastewater and stormwater issues as described in Recommendation #4.**

This clearinghouse would be organized by specific pollutants and sources. It would contain information on monitoring data, control strategies, and the effectiveness of these control strategies. The CD-ROM described in Recommendation #8 in the previous subsection could be included as part of this clearinghouse.

2. **Develop monitoring and sampling protocols to be used for residential/ commercial wastewater and stormwater.**

The protocol would specify various parameters including equipment, sample type, sampling site criteria, sampling frequency and duration, clean techniques, quality assurance/quality control methods, data analysis methods, and detection limits. The developed protocols would allow data from different studies to be compiled and compared throughout the country.

3. **Characterize non-stormwater discharges through a monitoring program as described in Recommendation #3.**

Few data are currently available for the wide range of non-stormwater discharges present in most communities. Representative monitoring data would allow stormwater management programs to focus their efforts more effectively.

4. **Conduct research to identify motivators that are most effective in changing behavior as described in Recommendation #7.**

Other programs (e.g., energy conservation and health care) have successfully used social marketing techniques and behavioral change principles to achieve desired results with respect to behavior modification. Research is needed as to the application of these principles to public education efforts regarding wastewater and stormwater pollution prevention issues.

5. **Develop methods of assessing effectiveness of source control programs as described in Recommendation #5.**

Most agency staff contacted for this project expressed a need for tools to measure program effectiveness. Development and use of these tools will help program managers to focus their resources on the most effective control measures and improve the overall results of their efforts.

APPENDIX A

SOURCE CONTROL ASSESSMENT CONTACTS

WERF Source Control Assessment Agency Contacts

Region	State	Organization/Agency	Contact	Phone No.
1	Massachusets	MA Office of Technical Assistance, 100 Cambridge St., Suite 2109, Boston, MA 02202	Grace Offen HHW Coordinator	617-727-3260 x 696 (p) 617-727-3827
1	Massachusets	Massachusetts Water Resource Authority	Kevin McManus	617-242-6000
1	Massachusets	MA Office of Technical Assistance, 100 Cambridge St., Suite 2109, Boston, MA 02202	Rick Reibstein Assist. Director	617-727-3260x688(p) 617-727-3827(f)
1	New Hampshire	State of New Hampshire, Dept. of Environmental Services, PO Box 95 - Hazen Dr., Concord, NH 03301	James T. Spaulding Supervisor	603-271-3503
1	Rhode Island	Save The Bay	Alison Walsh	401-272-3540
1	Rhode Island	Narragansett Bay Commission	Thomas P. Uva Pretreatment Program Manager	401-277-3738
2	New Jersey	NJ Environmental Federation, 94 Church St. New Brunswick, NJ 08901	Amy Goldsmith State Director	908-846-4224 (p), 908-846-4320 (f)
2	New Jersey	USEPA, 2890 Woodbridge Ave. Edison, NJ 08837-3679	Richard Field Leader Wet Weather Flow Program	908-321-6674(P) 908-906-6990(f)
2	New York	Region 2 EPA	Janet Sapadin	212-637-3584
2	New York	USEPA Region 2, 290 Broadway, NY NY 10007-1866	Sergio Bosques Environmental Engineer	212-637-3717(p) 212-637-3721(f)
2	New York	NY/NJ Harbor Estuary Program	Seth Ausubel	212-637-3793
2	New York	Silver Council (Nixon, Hargrave, Devans, & Doyle	Libby Ford Senior Environmental Health Engineer	716-263-1606
3	Maryland	Washington Suburban Sanitary Commission	Michael Armorer Unit Manager, Industrial Discharge Control Unit	301-206-8526
3	Washington D. C.	Government of the District of Columbia	Deepak Butani	202-645-6299
3	Virginia	Alexandria Sanitation Authority	Vibeke Lindblom Pretreatment Program Manager	703-549-3381
3	Virginia	City of Alexandria	Warren Bell Deputy Director for Engineering	703-838-4327
3	Virginia	Millenium Science and Engineering, Inc.	Dale Rice Manager, Hazardous Waste & Pollution Prevention	703-734-1090
4	Florida	Lee County Div. of Nat. Res. Mngmt., 2012 Altamont Ave, Fort Myers FL 33901	Dale Nottingham SQG PRogram Supervisor	941-335-2141(p) 945-338-3289
4	Florida	Bureau of Solid and Hazardous Waste, Mail Station 4570, 2600 Blair Stone Rd., Tallahassee, FL 32399-2400	John Scarboro	904-488-0300(p) 904-921-8061(f)
4	Florida	Broward County Dep. of Nat. Res. Protection, 218 SW 1st Ave, Fort Lauderdale, FL 33301	Kay Gervasi Program Manager	305-519-1257(p) 305-765-4804(f)

WERF Source Control Assessment Agency Contacts

Region	State	Organization/Agency	Contact	Phone No.
4	Florida	Dade County Dept. of Env.Res. Mngmt., 33 SW Z(?) Ave., Suite 1200, Miami, FL 33130	Lori Cuniff Chief, Sustainable Environment & Education Office	305-372-6828(p) 305-372-6760(f)
4	Florida	University of Central Florida, PO Box 162993, Orlando, FL 32816-2993	Marty Wanielista Dean, College of Engineering	407-823-2156(p) 407-823-5483(f)
4	North Carolina	NC Division of Environmental Management, PO Box 29535, Raleigh, NC 27626-0535	Bradley Bennett Stormwater Supervisor	919-733-5083x525(p) 919-733-9919
4	North Carolina	Waste Reduction Resource Center, PO Box 29569, Raliegh, NC 27626-9569	Jim Grovenstein, Gary Hunt	800-476-8686(p) 919-715-6794(f)
4	North Carolina	City of Raleigh Public Utilities, PO Box 590, Raleigh NC 27602	Burrell C. Brock, III Industrial Pretreatment Coordinator	919-662-5700
4	Tennessee	Tennessee Valley Authority, 1101 Market St. WR4P, Chattanooga, TN 37402	Charles L. McEntyre Waste Reduction Engineer	423-751-7310(p) 423-751-8404
4	Tennessee	City of Memphis, 664 St. Jude Street Memphis, TN 38105	James H. Baker Environmental Projects Coordinator, Stormwater	901-529-0237
5	Illinois	USEPA Region 5, 77 W. Jackson St., Chicago, IL 60604	Peter Swensen Environmental Engineer	312-886-0236(p) 312-886-7804(f)
5	Indiana	Indiana Department of Environmental Management	David Lawrence	219-881-6712
5	Michigan	Rouge Program Office, 220 Bagley Avenue, Suite 920, Detroit, MI 48226	Noel Mullett (or Karen Reaume, ECT)	313-961-0700
5	Minnesota	Western Lake Superior Sanitary District	TimTuominen	218-722-3336
5	Wisconsin	Wisconsin Department Of Natural Resources	James Helm Staff Assistant Stormwater Program	608-266-2779
5	Wisconsin	Wisconsin Department of Natural Resources	Roger Bannerman Standards and Monitoring Section	608-266-9278
6	New Mexico	City of Albuquerque, 4201 Second Street SW, Albuquerque, NM 87105	Robert Hogrefe Pretreatment Program Manager	505-873-7004(p) 505-873-7087(f)
6	Oklahoma	Region 6 EPA	Ken Teague	214-665-6687
7	Iowa	Iowa Waste Reduction Center	Marci Carter	319-273-2079
7	Iowa	Iowa Department of Natural Resources, Iowa Waste Reduction and Assistance Program (WRAP - Julie)	Monica Wnuk, Julie Nelson Environmental Protection Division	515-281-7017
7	Kansas	Region 7 EPA	Steve Wurtz	913-551-7315
8	Colorado	City of Boulder, Boulder CO 80301	Caroline Erickson Field Specialist, Industrial Pretreatment Program	303-441-3251
8	Colorado	City of Ft. Collins	Kevin McBride	970-224-6023

WERF Source Control Assessment Agency Contacts

Region	State	Organization/Agency	Contact	Phone No.
8	Colorado	Colorado Water Quality Control division, 4300 Cherry Creek Dr. South, WQCD-PE-BZ, Denver, CO 80224--1530	Sarah Johnson STormwater Unit leader	303--692-3609
8	Montana	Montana Pollution Prevention Program	Janice Secretary	406-994-3451
8	Montana	DEQ-WQD, PO Box 200901, Helena, MT59620-0901	Roxann Lincoln Water Quality Specialist	406-444-2406
9	Arizona	City of Phoenix, Street Transportantion Department, 200 West Washington, Phoenix, AZ 85003	Jeff Menke Senior Water Quality Inspector	602-256-3190(p) 602-495-2016(f)
9	Arizona	City of Phoenix, Water and Wastewater, 2303 West Durango St., Phoenix, AZ 85009	Lori Sundstrom Pollution Control Superintendant	602-262-1854 (P) 602-534-7151 (f)
9	Arizona	City of Tempe, PO Box 5002, Tempe, AZ 85280	Malcolm Montgomery Environmental Investigator	602-350-2689
9	California	Central Contra Costa Sanitary District, 5019 Imhoff Pl., Martinez, CA	Bart Brandenburg Source Control Supervisor	510-229-7361 (p) 510-372-7635 (f)
9	California	South Bayside System Authority	Bill Kiokke Source Control Supervisor	415-591-7121
9	California	City of Los Angeles Public Affairs Office	Chuck Ellis Public Information Director	213-847-5206
9	California	East Bay Municipal Utility District, PO Box 24055, Oakland, CA 94623-1055	Dan Kimm, Stan Archaki Pollution Prevention Program	510-287-1622
9	California	San Francisco Water Pollution Prevention Program	Daniel Rourke	415-695-7377
9	California	City of Livermore	Darren Greenwood	510-373-5233
9	California	Hazardous & Toxics Materials Office, City of LA, 201 N. Figueroa St. #200, Los Angeles, CA 90012	Donna Chen Program Manager	213---580-1079
9	California	Union Sanitary District, PO Box 5015, Fremont, CA 94536	Donna Weis	510-790-0110
9	California	Sacramento Regional County Sanitation District, 9680 Ecology la. Sacramento Ca, 95827	Glen Del Sarto, Sam Harader Industrial Waste Program Manager	916-855-8454(p) 916-855-5874(f)
9	California	City of Arcata, 736 F Street, Arcata CA 95521	Jill Geist Water Quality Technician	707-822-8184 (p) 707-822-8018 (f)
9	California	City of Hayward, 24499 Soto Road, Hayward, CA 94544	Joe Mendoza Source Control Inspector	510-881-7903
9	California	Riverside County Transportation and Land Management Agency, PO Box 1090 Riverside CA 92502	John Ristow, Teresa Summers Sr. Transportation Planner	909-275-1775
9	California	Palo Alto Regional Water Quality Control Plant	Kelly Moran	415-329-2421
9	California	City of Simi Valley	Larry Whitney, Bob Zomalt Source Control Supervisor	805-583-6420,6462

WERF Source Control Assessment Agency Contacts

Region	State	Organization/Agency	Contact	Phone No.
9	California	San Francisco Bay Regional Water Quality Control Board	Selina Louie	510-286-4239
9	California	Alameda Countywide Clean Water Program	Sharon Gosselin	510-670-6547(p) 510-670-5262(f)
9	California	Santa Monica Bay Restoration Project	Stephanie McDonald	213-266-7667
9	California	CGvL Engineers, 7 Corporate Park Drive, Irvine , CA 92606	Rich von Langen	714-476-6050
10	Washington	King County Water Pollution Control Division, 130 Nickerson ST., Suite 200 Seattle WA 98119-1658	Douglas Hildebrand Industrial Waste Program Officer	206-689-3032
10	Washington	King County Hazardous Waste Management Program	Ray Carveth, Lorie Foster	206-689-3053
10	Washington	Drainage and Wastewater Utility, 660 Dexter Horner Building, 710 Second Ave, Seattle, WA 98104-1709	Robert Chandler Senior Environmental Analyst	206-684-7597

APPENDIX B

COLLECTING INFORMATION FOR THE PROJECT

The following guidelines were used to collect information in two parts. The first part was conducted over the telephone following the guidelines in the sections entitled Introduction and General. The second part consisted of the numbered sections and was conducted according to the contact's preference by phone, fax, or e-mail.

INTRODUCTION

(Introduce yourself and describe the project. Use the following paragraph as a guideline)

Larry Walker Associates (LWA) was awarded a grant from the Water Environment Research Foundation to conduct an assessment of existing information and programs concerning residential and commercial sources of wastewater and stormwater pollution. The first task in this project is to review the relevant literature and program information. Specifically, we are looking for information in the following areas:

- Identification of pollutants of concern from residential and commercial sources (e.g., data and descriptions of studies)
- Source control strategies used to address commercial and residential sources
- Effectiveness of these strategies used to address commercial and residential sources
- Stormwater and wastewater pollution prevention activities and public education programs

LWA and Harris and Company are developing a bibliography of this information. We would appreciate it if you would answer the following questions as they pertain to your program and provide us with a list of reports, articles, etc., that describe the information.

(Next, keep a record of each call. Start with the following basic information)

Name of person spoken to:

Title:

Organization:

Areas of expertise (e.g., stormwater, wastewater, pollution prevention, public education):

How do you want to receive and respond to our survey? (phone interview, fax, or e-mail)

GENERAL (Ask all contacts the following questions on the phone)

What are the pollutants of concern in your region (or for your agency)?

Which bodies of water are affected?

Which agencies, pretreatment programs, regional boards, other groups are considered leaders or have done the most work in **Water** (wastewater or stormwater) pollution prevention?

Who are contacts for these programs (phone number, address, fax number, e-mail)?

Stormwater contact?

Wastewater pollution prevention contact?

Outreach/public education contact?

The rest of the information can be obtained in a phone interview or faxed or e-mailed to the contact after the above phone conversation has been conducted. Wastewater and Stormwater contacts should respond to Sections I, II, III, IV, and V. Public education contacts should respond to Sections I, V, and VI.

WATER ENVIRONMENT RESEARCH FOUNDATION
RESIDENTIAL AND COMMERCIAL SOURCE CONTROL ASSESSMENT

Larry Walker Associates (LWA) was awarded a grant from the Water Environment Research Foundation to conduct an assessment of existing information and programs concerning residential and commercial sources of wastewater and stormwater pollution. The first task in this project is to review the relevant literature and program information. Specifically, we are looking for information in the following areas:

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- Source control strategies used to address commercial and residential sources
- Effectiveness of these strategies used to address commercial and residential sources
- Stormwater and wastewater pollution prevention activities and public education programs

LWA and Harris and Company are developing a bibliography of this information. We would appreciate it if you would answer the following questions as they pertain to your program and provide us with a list of reports, articles, etc. that describe the information. WE ARE NOT ASKING FOR COPIES OF THE MATERIALS AT THIS TIME, JUST A LIST OF WHAT IS AVAILABLE. We may ask to review the actual materials in the near future. We appreciate your assisting us with this project.

Please send your responses and lists to either person listed below:

Betsy Elzufon
Larry Walker Associates
509 Fourth Street
Davis, CA 95616
Phone: 916-753-6400
FAX: 916-753-7030
E-mail: lwa@davis.com

Christine Harris
Harris & Company
P.O. Box 72237
Davis, CA 95617
Phone: 916-7588-2100
Fax: 916-758-2211
E-mail: harcomp@aol.com

If your area of work or expertise is stormwater or wastewater or pollution prevention, please answer sections I through V. If your area of work or expertise is public education, please answer sections I, V, and VI.

I. CONTACT INFORMATION

Name:

Title:

Organization:

Address:

Phone number:

Fax number:

E-mail address:

Are there any other programs or people that you would recommend we contact?

II. SOURCES

How are pollutants of concern identified and prioritized?

How are sources of pollutants identified and prioritized (e.g., sampling, wastewater monitoring, other methods) ?

Which commercial sources (businesses, commercial activities - e.g., printers, cooling towers, auto repair shops, car washes) have been evaluated as sources of stormwater or wastewater pollution?

Which residential sources have been evaluated as sources of wastewater or stormwater pollution (e.g., home pesticide use, household products, laundry graywater)?

Has corrosion of plumbing been evaluated as a source of pollutants?

Has the source water been evaluated as a source of pollutants?

For any reports or articles on the programs/ materials described in this section, please provide the title, date, author & phone number, and a paragraph describing it if possible.

III. SOURCE IDENTIFICATION

Has monitoring of the sewer system or storm drain system been conducted to identify commercial or residential sources?

Has sampling been conducted for individual businesses or residential areas?

Has commercial or residential monitoring been conducted as part of a Local Limits evaluation?

Have specific products (e.g., printers ink, used motor oil, commercial pesticides, household cleaners) been analyzed or evaluated?

What other methods have been used to identify sources?

For any reports or articles on the programs/ materials described in this section, please provide the title, date, author & phone number, and a paragraph describing it if possible.

IV. SOURCE CONTROL STRATEGIES

What source control strategies or pollution prevention activities have been developed for each source (e.g., permitting, public outreach, focused business outreach, financial incentives, development of Best Management Practices)?

Have other pollution prevention activities been conducted that may not target a specific source?

Engineering studies?

Economic studies?

Evaluation of environmental benefits?

For any reports or articles on the programs/ materials described in this section, please provide the title, date, author & phone number, and a paragraph describing it if possible.

V. PROGRAM EFFECTIVENESS

Have public awareness surveys been conducted?

Have responses to outreach been tracked (e.g., logging phone calls made in response to a brochure, advertisement, etc.)?

Have buying habits been tracked?

Have surveys been conducted?

Has wastewater levels of pollutants been tracked?

Have cost analyses been conducted?

Other methods of measuring effectiveness?

For any reports or articles on the programs/ materials described in this section, please provide the title, date, author & phone number, and a paragraph describing it if possible.

VI. PUBLIC OUTREACH

What is the goal and/or purpose of the public outreach/ information program?

Methods of outreach - workshops, flyers, radio, newspaper, television, school programs.

Audiences - businesses, business groups, adults, students, environmental organizations, service organizations.

What types of public information materials have been used or are being used in the public information program? **(Please provide titles and brief description of these materials)**

Advertisements (magazine, billboards, other)

Brochures

Displays, exhibits

fact sheets

Guide books/ How-to booklets/ Manuals

Newsletters

Posters

Calendars

Press/ Media Kits

Public Service Announcements

School curriculum/ program

Slide shows/ speakers bureau

Specialty items/ give-aways

Storm drain stenciling program

Videos

Other materials

What languages are used in the public information materials?

Are the materials developed by the agency or by consultants?

Have you won awards or received other forms of recognition for the public information program?

For any reports or articles on the programs/ materials described in this section, please provide the title, date, author & phone number, and a paragraph describing it if possible.

APPENDIX C

ADDITIONAL MONITORING AND SOURCE IDENTIFICATION STUDIES

Table C-1. Summary of Additional[1] Monitoring and Source Identification Studies[2]

Region	Agency (and affected body of water, if specified)	Type of Monitoring	Pollutants Evaluated	Source ID Methods	Sources Targeted
I	MA Office of Technical Assistance for Toxics Use Reduction	WW, SW	oil & grease	sampling, literature	restaurants, household products
I	MA Water Resource Authority (MA Bay, Boston Harbor)	WW	Cu, Pb, Hg, Petroleum hydrocarbons, pesticides	sampling	• 5 yrs. strictly residential data • starting to look at commercial • some sampling of car washes
IV	NC Division of Env. Management	SW	not specified	sampling, MS4 programs, literature	those included in MS4 programs (unspecified)
IV	Dade County Dept. of Env. Resources Management	WW, surface water	Pesticides, Hg, PB, Organic Solvents	sampling=all businesses on sewer & septic are sampled regularly, citizen complaint results in residential sampling	residential (used motor oil, home chemicals, litering), lead in drinking water (corrosion)
IV	Lee County Div. of Natural Resources Management	WW	not specified	sampling, field assessment/verifications	commercial areas and indiv. businesses (unspecified)
V	City of Muncie	WW,SW	Cu, Zn, others (not specified)	monitoring urban sewers, residential areas	laboratories, other (non specified)
VII	Kansas Dept. of Health	WW	chlorine, ammonia, Cu, Hg	monitor streams & rivers	not specified
VII	Johnson Co. Unified Wastewater Dist. (Indian Creek)	WW, SW	Cu, pesticides (diazinon)	tox. testing during wet weather, monitoring inflow	not specified

R0026214

Table C-1, cont. Summary of Additional[1] Monitoring and Source Identification Studies[2]

Region	Agency (and affected body of water, if specified)	Type of Monitoring	Pollutants Evaluated	Source ID Methods	Sources Targeted
VII	Lincoln/Lancaster County POTW (Salt Creek)	WW	ammonia, Hg, diazinon, atrizene, chlorpyrifos	waste inventories	auto repair, photo processing, other (unspecified)
VIII	Denver Regional Council of Governments (South Platte River, all streams, etc.)	SW	dissolved metals, nitrogen, phos., ammonia, DO	not specified	abandoned mines
VIII	DEQ-WQD, Stormwater Program (Montana) (Ashley Creek, Flathead Lake, others)	SW	sediment, BOD, COD, hydrocarbons	permit sampling, research projects, complaint investigation sampling, SIC codes	commercial sources (unspecified), home pesticide/herbicide use, household products, paints, solvents, fuel, etc.
IX	East Bay Municipal Utility District (EBMUD) (San Francisco Bay)	WW	copper	EBMUD plant interceptor, Bay monitoring data, self monitor. data, literature	radiator shops, dry cleaners, photoprocessors, auto repair/body, printers, boatyards, furniture finishers
IX	City of Livermore (San Francisco Bay)	SW, receiving	not specified	limited sampling, knowledge of processes used at different facilities	vehicle service facilities, machine shops, analyzed "fountain" solution from printers
IX	City of Simi Valley	WW	Ag, Ammonia, Cu, Chloride, TSS	sampling specific businesses & residential areas, monitor. recv. water	Commercial: metal finishers, medical facilities, photoprocessors, automotive repair, retaurants, outdoor storage Residential: pools & spas, water softners

Table C-1, cont. Summary of Additional[1] Monitoring and Source Identification Studies[2]

Region	Agency (and affected body of water, if specified)	Type of Monitoring	Pollutants Evaluated	Source ID Methods	Sources Targeted
IX	Sacramento County Regional Sanitation District	WW	not specified	Residential: intensive sampling 1990-96, Comm.: sampling businesses	radiator shops, restaurants, dry cleaners, wood finishers, printers
IX	City of Tempe	WW	Hg, As, Cu, Pb	SIC codes, sampling	commercial printers, car washes, commercial laundries, auto repair shops, jewelers, home pesticide use, household products (Cu sulfate, TCE), laundry greywater

[1] Additional to studies discussed in detail in Chapter 2.0.

[2] Source: project surveys and personal communications.

R0026216

APPENDIX D

AGENCIES PROVIDING PUBLIC EDUCATION MATERIALS

Table D-1. Summary of Regions in United States that Provided Public Education Materials for WERF Study

State	Region	Agencies	Type/Focus of Materials
RI	1	University of Rhode Island	Computer-based curriculum for junior high school on water resources
RI	1	Save the Bay, Providence, Rhode Island	Print materials on activities related to stormwater pollution; reporter=s guide to water quality issues
NY	2	New York State Dept. Of Environmental Conservation, Albany	Materials on watersheds
MD	3	Center for Watershed Protection, Silver Spring, Maryland	Teachers guide on water monitoring program
VA	3	Terrene Institute, Alexandria Virginia	Newsletters and fact sheet on wetlands, urban runoff, and classroom materials
DC	3	Metropolitan Washing Council of Governments	Pamphlet on stormwater issues
VA	3	Alliance for Chesapeake Bay, Richmond, Virginia	Print materials on preventing pollution of Chesapeake Bay, including sediment/erosion control
MD	3	National Oceanic and Atmospheric Administration, Maryland	Fact sheet and article on toxics in Chesapeake Bay
DC	3	National Safety Council, Washington D.C.	Guide to media and reporters on coastal issues
VA	3	Water Environment Federation, Alexandria, Virginia	Various print materials on a range of environmental protection topics
MD	3	Ecosystem Recovery Institute, Freeland, Maryland	Pamphlet on education resources training programs
FL	4	Dept. Of Environmental Resources Management/U.S. Coast Guard, Metro-Dade County	Large number of materials, primarily focusing on things people can do to prevent stormwater and sanitary sewer pollution, recycling
AL	4	Reynolds Metals Company, Muscle Shoals, Alabama	Application award for stormwater program
FL	4	State of Florida, Dept. Of Environmental Protection, Tallahassee	Various materials on stormwater management

Table D-1, cont. Summary of Regions in United States that Provided Public Education Materials for WERF Study

State	Region	Agencies	Type/Focus of Materials
FL	4	State of Florida, Dept. Of Health and Rehabilitative Services	Booklet on radon in water
FL	4	Sarasota County Natural Resources Dept./Sarasota Bay Project	Booklet on various citizen activities to protect bay
WI	5	University of Wisconsin	Booklet on stormwater; various pamphlets on watersheds and characteristics of local water bodies, flood control, and stewardship; environment-oriented materials for children; various print materials for general public on activities that cause stormwater pollution
WI	5	Wisconsin Natural Resources	Booklet on Green Machine program
WI	5	Wisconsin Dept. Of Natural Resources	Various print materials on things residents can do to prevent stormwater pollution
MI	5	West Michigan Environmental Action Council	Print materials on stormwater pollution prevention
MN	5	Minnesota Pollution Control Agency	Various print materials on several environmental issues; fact sheets on environment-friendly products and practices; information on agriculture and water quality
MI	5	Lake Michigan Federation	Guide for citizens, educators and business on environmental issues related to Lake Michigan
MN	5	Western Lake Superior Sanitary District	Pamphlet on mercury
NM	6	City of Albuquerque, New Mexico	Pamphlets and advertisements on pollution prevention
TX	6	Lower Colorado River Authority, Austin Texas	Print materials on watershed management
OK	6	City of Oklahoma City, Oklahoma	Reports on BMPs, public education program, biomonitoring/diazinon
LA	6	Louisiana Dept. Of Environmental Quality, Baton Rouge	Various print materials that target several possible sources of pollution to stormwater and sanitary sewers
TX	6	City of Greenville, Texas	Various materials and articles about efforts to reduce use of diazinon
IA	7	Soil and Water Conservation Society, Ankeny, Iowa	Comic books on water quality and other environmental issues

Table D-1, cont. Summary of Regions in United States that Provided Public Education Materials for WERF Study

State	Region	Agencies	Type/Focus of Materials
MO	7	Mississippi River Basin Alliance, St. Louis, MO	Pamphlet on community participation with MRBA
MT	8	The Montana Watercourse, Bozeman	Print materials with the theme "We all live downstream"
AZ	9	City of Phoenix, Arizona	Various print and give-away materials and PSAs targeting solutions to stormwater pollution
CA	9	Santa Monica Bay Restoration Project	Summary of public education messages, targeted pollutants, and target audiences
CA	9	City of Palo Alto Recycling Program	Pamphlet on recycling and HHW
CA	9	City of Sacramento Utilities Dept.	Various print materials -- information about stormwater pollution for different targeted groups
CA	9	San Diego Regional Household Hazardous Materials Program	Comic book on HHW
CA	9	City of Palo Alto Palo Alto Storm Drain Program and Regional Water Quality Control Plant	Various print materials on a range of environmental issues; series of pamphlets targeting activities that cause both stormwater and sanitary system pollution; videotape on preventing pollution in creeks
CA	9	Contra Costa County Environmental Health/Santa Clara Valley Nonpoint Source Pollution Program	Various print materials targeting activities that cause stormwater and sanitary system pollution
CA	9	Santa Clara Valley Nonpoint Source Pollution Control Program	Fact sheets and pamphlets focused on stormwater and urban runoff
CA	9	San Francisco Water Pollution Prevention Program	Fan-out booklets on environmentally-friendly do-it-yourself / gardening activities
CA	9	Central Contra Costa County Sanitary District	Pamphlet on pesticide alternatives Survey, public education plan, pollution prevention plan
CA	9	South Bay Water Recycling, San Jose	Newsletter
CA	9	San Francisco Dept. Of Public Works	Awareness surveys -- BMP and household toxics
CA	9	City and County of San Francisco	Newsletter
CA	9	City of Benecia	Various print materials on stormwater pollution prevention

Table D-1, cont. Summary of Regions in United States that Provided Public Education Materials for WERF Study

State	Region	Agencies	Type/Focus of Materials
CA	9	Sacramento Stormwater Management Program	Various print materials, general information about stormwater pollution targeting different groups
CA	9	Alameda County Urban Runoff Clean Water Program	Various print materials, PSA, and giveaways. Materials focus on management issues, demonstration project, and activities that cause stormwater and sanitary system pollution
CA	9	The Lindsay Museum	Various print materials on water pollution, stormwater, and volunteer programs
CA	9	Water Education Foundation, Sacramento	General water education
CA	9	East Bay Municipal Utility District, Oakland	Various print materials on activities that cause sanitary system pollution
CA	9	City of Los Angeles	Stormwater public education program, various print materials, billboard/poster
CA	9	Caltrans	Pamphlet on environmentally-friendly vegetation control
CA	9	City of Rancho Cucamonga	Coloring books about the environment and recycling
CA	9	Central Marin Sanitation Agency	Videotape featuring school children
CA	9	City of Santa Rosa	Print materials by high school students
CA	9	City of Davis	Guide on City services related to environment; storm drain stenciling
CA	9	State Dept. Of Water Resources	Booklet on graywater
CA	9	Vallejo Sanitation and Flood Control District	Poster on wastewater treatment plant
CA	9	Riverside County Flood Control and Water Conservation District	Various print and give-away materials on stormwater education
CA	9	San Francisco Estuary Project	Storm drain stenciling
CA	9	City of Sunnyvale	Various print materials targeting activities that cause stormwater and sanitary sewer pollution
CA	9	City of Bellevue, Storm and Surface Water Utility	Booklet -- overall program

Table D-1, cont. Summary of Regions in United States that Provided Public Education Materials for WERF Study

State	Region	Agencies	Type/Focus of Materials
WA	10	Washington Toxics Coalition	Consumer guide of less toxic products
WA	10	Seattle Tilth Association	Brochure on pesticide free gardening
WA	10	Puget Sound Water Quality Action Team	Newsletters and publications list -- overall program
WA	10	Seattle Drainage and Wastewater Utility	School education program materials -- videos and teachers manuals
WA	10	Municipality of Metropolitan Seattle and the Seattle King County Dept. Of Public Health	Pamphlet -- Household Hazardous Waste
WA	10	King County Surface Water Management Division	Various print materials on the Community Stewardship Program
WA	10	City of Seattle Solid Waste Utility	Evaluation of Green Gardening program
WA	10	City of Olympia, Public Works Dept.	Various print materials for a range of interests about stormwater and pollution prevention
		U.S. Environmental Protection Agency	Various print materials on pollution prevention, radon, and environmentally-friendly lawn maintenance

APPENDIX E

EXAMPLES OF PUBLIC EDUCATION MATERIALS

The following pages are sections of public education materials reviewed and discussed in this report. These publications illustrate a cross-section of the messages, regional styles, targeted pollutants and activities, audiences, and strategies used to communicate stormwater/urban runoff and pollution prevention issues today. Please note that only portions of the brochures, flyers, guides, and posters are reproduced in this appendix. The organizations that provided the materials are listed at the beginning of the appendix.

	PAGE NUMBER
Organizations Providing Materials	**E-3**
Messages	**E-7**
Regional Flavor	**E-21**
Targeted Pollutants and Activities	**E-37**
Audiences	**E-61**
Strategies	**E-73**

MESSAGES

1. **"Are you pouring water quality down the drain?"**
   By the City of Albuquerque, New Mexico
   505-768-3654

2. **"Solution to Stormwater Pollution ... What's Down that Dark Drain?"**
   By the Sacramento Stormwater Management Program
   Sacramento, California
   916-433-6369

3. **"Louisiana Storm Drain Stencil Program"**
   By the Louisiana Department of Environmental Quality
   Baton Rouge, Louisiana
   504-765-0634

4. **"Estuarywise ... 100 Tips on How You Can Prevention Pollution of Our Bay and Delta"**
   By the San Francisco Bay Estuary Project
   Oakland, California
   510-286-0460

5. **"Bay Repair Kit"**
   By the Sarasota County Natural Resources Department, Sarasota Bay Project, and HRS -- Manatee County
   Sarasota, Florida
   813-378-6128

REGIONAL FLAVOR

6. **Stickers ... Feed Me Clean Water, Louisiana**
   By the Louisiana Department of Environmental Quality
   Baton Rouge, Louisiana
   504-765-0634

7. **"Wanted ... Your help is needed in locating the following notorious wastewater pollutants"**
   By the City of Phoenix, Arizona
   602-262-1859

8. **Flo the Raccoon, hot-line card.**
By the Palo Alto Storm Drain Program
Palo Alto, California
415-329-2129

9. **Flo the Raccoon, "Hey Let's Talk About Protecting the Bay"**
By the Palo Alto Storm Drain Program
Palo Alto, California
415-329-2129

10. **"How To Be a Clean Water Rainger"**
By the New Jersey Department of Environmental Protection
Trenton, New Jersey
609-633-1179

11. **"New York State Watersheds"**
By the New York State Department of Environmental Conservation
Division of Water
50 Wolf Road, Albany, New York 12233-3501

TARGETED POLLUTANTS AND ACTIVITIES

12. **"Home Maintenance Tips For a Cleaner Bay"**
By the Santa Clara Valley Nonpoint Source Pollution Control Program
San Jose, California
408-265-2600 or 408-927-0710

13. **Series of Brochures "Vehicle Shop Practices for a Cleaner Bay"**
By the Bay Area Wastewater Treatment Plants and Stormwater Management Agencies
Various agencies
510-670-5543

14. **"1-800-94-RE*USE*" ... Waste Oil Recycling Point-of-Purchase Brochure**
By the San Mateo Countywide Stormwater Pollution Prevention Program
Redwood City, California
415-363-4708

15. **"The Less Toxic Garden"**
By the San Francisco Water Pollution Prevention Program
San Francisco, California
415-695-7375

16. **"Pollution From Surface Cleaning"**
By the Bay Area Stormwater Management Agencies Association
and the San Francisco Bay Regional Water Quality Control Board
Oakland, California
510-286-0615

17. **"Diazinon Use Discouraged" -- CITYSCOPE Summer 1992**
"Free Seminar on Fire Ant Control Planned Tuesday" -- Greenville Herald Banner, April 10, 1994
"Seminar to help fight pesky critters" -- Greenville Herald Banner, July 4, 1994
"There are ways to control pests" -- Greenville Herald Banner, January 23, 1995
By the Office of Public Education for Greenville Water Utilities
Greenville, Texas
903-457-3149

18. **"Good Practices to Protect Creeks and Bay ... Guidelines for Restaurants, Grocery Stores, Cafeterias, Bakeries, Delicatessens"**
By the Santa Clara Valley Nonpoint Source Pollution Control Program
San Jose, California
408-265-2600 or 408-927-0710

AUDIENCES

19. **"Spreading the Word on Storm Water ... A Strategy for the Milwaukee Area"**
By the Southeast Area Water Quality Extension, University of Wisconsin, Extension for the Wisconsin Department of Natural Resources
Milwaukee, Wisconsin
414-263-8641 or 414-263-8696

20. **"Stop pouring money down the drain ... Become a Business for Clean Water"**
By the King County Surface Water Management Division
Seattle, Washington
206-296-6519

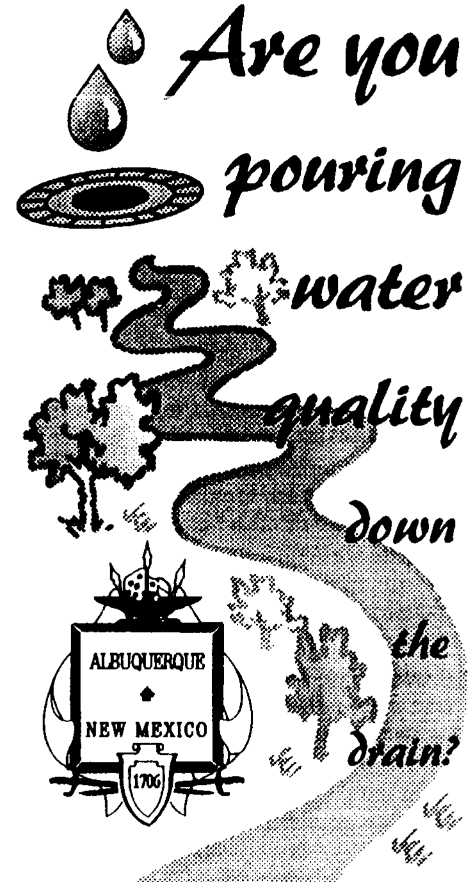
21. **"Water You Doing? -- Middle School Education Program"**
By the Seattle Drainage & Wastewater Utility
Seattle, Washington
206-684-7591

22. **"Promoting Stewardship of Puget Sound ... More PIE* Success Stories"**
*Public Involvement and Education
By the Puget Sound Water Quality Authority
Olympia, Washington
360-407-7300

23. **"Downstream News", Spring 1996**
By the King County Surface Water Management Division
Seattle, Washington
206-296-6519

24. **"1996 Community Stewardship Network Directory"**
By the King County Surface Water Management Division and King County Department of Natural Resources
Seattle, Washington
206-296-6519

MESSAGES



An informational brochure
from the
City of Albuquerque
Public Works Department
Solid Waste Department
and the Environmental Health Department

City of Albuquerque

This brochure printed on recycled paper

And you...

The Water Quality Team

Help! lines

Please contact any of the following for information on environmental concerns:

Household Hazardous Waste Information 768-2600
Environmental Health Department

Used Oil Recycling 768-2636
Environmental Health Department

Recycling Information 761-8100
Solid Waste Department

PUBLIC WORKS DEPARTMENT:

Wasted Water Hotline 857-8031

Water Conservation City Line
843-6060, Category WELL (9355)

Stormwater Pollution Hotline
768-3003

Stormwater / Urban Runoff and Pollution Control Information
768-3654

Cross Connection / Backflow Prevention & Control 857-8215

Industrial Waste 873-7004

Waste Minimization & Pollution Prevention Information 873-7051

Industrial Waste Inspections
873-7032

Industrial Waste Engineer 873-7047

Environmental Engineer 873-7040

TTY Users *may call any number listed in this brochure through Relay New Mexico* 1-800-659-8331

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R0026229

Is your water quality going... ...down the drain?

What goes down the drain does not simply go away. Except for homes with septic tanks, all water washed down the drain or flushed down the toilet in Albuquerque goes to the City's Southside Water Reclamation Plant. At the plant, suspended solids, bacteria, and some treatable metals are removed. To destroy any remaining bacteria, the wastewater is chlorinated. Finally, this water is dechlorinated before being released to the Rio Grande, a cultural lifeblood for the state. The waters of the Rio Grande provide an indispensable resource for agriculture, wildlife, industry and communities downstream. Think about what might be going down the drain!

Did you know that many substances that enter the sewer system can't be removed during the treatment process? Those substances that enter the storm drain system are not treated at all! Anything poured into a gutter or a storm drain, such as used motor oil or antifreeze, flows directly to the Rio Grande, usually via neighborhood arroyos.

It may surprise you to find out that the Rio Grande supports a riparian habitat along its banks. Water birds, reptiles, amphibians, aquatic vegetation, and fish all inhabit the river downstream from the treatment plant. The Rio Grande also supports one of the largest cottonwood forests in the world.

The natural life in this habitat is endangered by substances that cannot be removed in treatment. The Albuquerque treatment facility does a great job, but current technology does not treat everything that could possibly be poured down the drain. Metals such as lead, silver and copper remain. If the effluent is heavily polluted by chemicals from products like used antifreeze or used motor oil when it reaches the plant, then the treated wastewater is also less pure as it enters the Rio Grande.

That's why your decisions count. Any time a toxic household or industrial product is poured thoughtlessly down the drain, it affects the quality of the habitats dependent on the river. In this state, due to the unique role of the Rio Grande, that includes many rural communities and wild areas.

Sometimes, the individual can make a big difference! While industry and business discharge is regulated by the Environmental Protection Agency and the City, for now household hazardous wastes are not. Voluntary individual responsibility is the most direct cure. Each time you decide not to pour, it counts!

A thoughtful home owner has many alternatives to pouring toxins down the drain. Be aware that many common household products, such as paints, cleaners, pesticides, herbicides and used oil, contain contaminants. Fixer used in home photo processing contains silver. Think before you pour!

Thanks for being part... of the water quality team!

Is what you're about to pour... ...giving you second thoughts?

Some Solutions:

Antifreeze Never pour antifreeze into a gutter! Recycling is available! Please call the Albuquerque Environmental Health Department at 768-2600.

Used Motor Oil Never dump oil on the ground or in a storm drain. Recycle this product! Find out about service stations and other sites in your neighborhood that will take in used oil for proper handling. Please call the Environmental Health Department at 768-2600.

Cleaners, pesticides and herbicides Make every possible attempt to use up leftover materials as specified on the label. Surplus can then be offered to others for their use. Try to use the less hazardous and non toxic products offered on the market, and buy only what you need. Finally, you can call the Albuquerque Environmental Health Department at 768-2600.

Paints & Solvents Use up as much of the leftover paint as possible. Offer unused portions to neighbors and theatrical groups, or use to cover graffiti. Cans with dried paint may be discarded in the trash. Paint thinner can be reused! Set aside the used thinner in a closed container until the paint particles settle out. The clear liquid may be strained for reuse. When the remaining paint sludge is dry, it may go in the trash. Photographic fixer with silver should be saved for recycling. Call the Environmental Health Department at 768-2600.

Car Washing Use low-phosphate soap or wax, or don't use soap at all, for washing your car. Try to wash the suds onto your lawn or desert landscaping instead of the gutter. Soap in small amounts will not damage a yard, but soap will harm fish and other aquatic wildlife in the river.

JUST FOR KIDS

STORMWATER POLLUTION SOLUTIONS

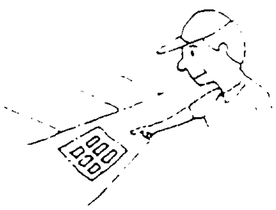
SACRAMENTO STORMWATER MANAGEMENT PROGRAM

YOU ARE THE

SOLUTION TO STORMWATER POLLUTION

KEEPING OUR YOUTH INFORMED OF WATER QUALITY ISSUES IN SACRAMENTO

WHAT'S DOWN THAT DARK DRAIN?



DO YOU EVER WONDER WHAT KIND OF "STUFF" GOES DOWN THOSE METAL GRATES ON STREET CORNERS? OR, WHERE THAT MYSTERIOUS DARK DRAIN LEADS TO? WHERE DOES IT GO?

WHEN IT RAINS OR WHEN YOU HOSE OFF YOUR DRIVEWAY OR SIDEWALK, THE WATER RUNS DOWN GUTTERS OR STORM DRAINS. THESE DRAINS CONNECT TO UNDERGROUND PIPES WHICH LEAD RIGHT TO CREEKS AND RIVERS. BUT A LOT OF OTHER STUFF, MOST OF IT TOXIC, WASHES INTO STORM DRAINS. LIKE MOTOR OIL AND ANTI-FREEZE FROM LEAKY CARS, TRASH, WEED KILLERS, PAINT, AND OTHER HOUSEHOLD TOXICS. YUCK! WE CALL IT **STORMWATER POLLUTION.**

WHEN YOU'RE RIDING IN A BOAT WITH YOUR FRIENDS, HAVE YOUR EVER SEEN GARBAGE FLOATING IN YOUR FAVORITE RIVER? THAT'S STORMWATER POLLUTION, TOO. SOME PEOPLE DON'T KNOW THAT STORMWATER POLLUTION CAN HURT FISH, BIRDS, AND CRITTERS THAT LIVE IN OUR CREEKS AND RIVERS. **BUT YOU AND YOUR FAMILY CAN HELP STOP IT!**

WHAT CAN YOU DO?

Tell your parents, teachers, friends, and relatives that you want to protect the Sacramento and American rivers! Here are some things you and your family can do to prevent stormwater pollution:

HOME

- Wash cars infrequently. Use biodegradable soap and a pistol grip nozzle on your hose.
- Recycle used motor oil and anti-freeze
- Once a month, remind your family to bring leftover toxic materials such as paint, cleaners, and pesticides to a household hazardous waste collection site.

SCHOOL

- Use water-based paints and wash up inside the classroom!
- Start a recycling center for paper, glass, and cans
- Always put trash in trash cans — never in the street!
- Ride your bike or the bus, or car pool with a friend. When it rains, air pollution turns into water pollution

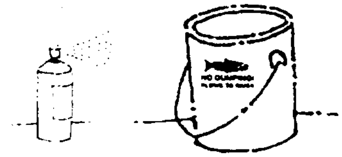
OUTDOORS

- Remind your parents not to apply fertilizer, pesticides, or weed killers if rain is forecast!
- If you see oil on your driveway, use kitty litter to soak up liquids, then sweep it up and throw it in the trash can.
- Use your pooper scooper for your pet and put poop in trash

WORKING TOGETHER, WE CAN ALL BE THE SOLUTIONS TO STORMWATER POLLUTION!

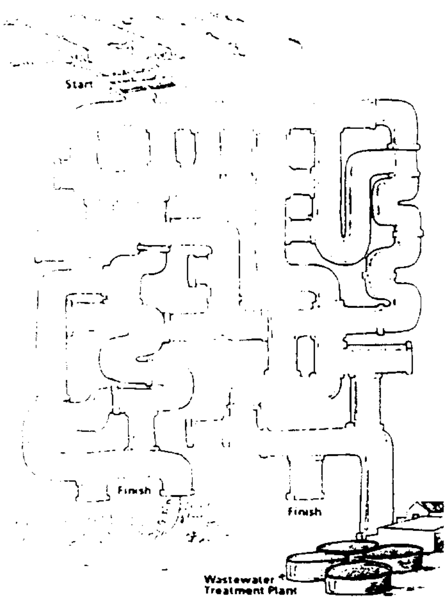
STENCIL A STORM DRAIN AT HOME OR AT SCHOOL

You can remind everyone who walks by a storm drain, "No Dumping — Flows to River!" so that everyone in Sacramento will know how important it is to protect our water. Call 433-6369 to borrow a stenciling kit and get more information.



PIPE MAZE

Follow the pipes to find out where rainwater goes after it runs down a storm drain. (Hint: There are two answers!)



WORD SEARCH

I	T	A	K	B	S	C	O	L	L	R	E	V	I	R
D	F	R	E	T	T	I	L	K	X	Q	I	R	B	O
G	M	S	O	R	C	J	C	V	H	Y	D	E	M	U
T	L	N	D	X	R	H	E	B	P	W	G	T	I	N
T	N	O	R	T	M	A	I	R	Z	A	F	A	B	E
A	A	I	I	H	W	E	N	U	B	L	O	W	K	K
I	H	T	V	L	A	N	T	R	A	W	B	C	M	O
B	Z	U	Y	M	T	D	A	R	Q	T	D	J	S	E
A	K	L	O	A	E	G	B	H	B	Y	Y	I	E	E
H	E	O	M	V	R	A	F	J	N	D	U	Q	T	F
H	U	S	T	O	R	M	D	R	A	I	N	O	H	I
S	C	Q	W	E	N	L	Q	D	F	F	R	B	Y	L
I	M	F	N	P	U	C	Y	A	K	X	I	Z	O	D
F	O	I	E	P	O	L	L	U	T	I	O	N	P	L
E	A	Q	B	E	C	D	O	P	F	E	E	U	C	I
R	X	I	H	O	K	A	K	T	G	Z	R	W	P	W

Here is a list of some of the things you might find in Sacramento. Can you find them in the puzzle?

- FISH
- POLLUTION
- CREEK
- STORM DRAIN
- RIVER
- SOLUTIONS
- WATER
- GARBAGE
- RAIN
- STORMWATER
- WILDLIFE
- OIL

TEST YOUR ENVIRONMENTAL KNOWLEDGE!!

1. In Sacramento, like most cities, the water that runs down the street and into the storm drain:

a. gets cleaned at a treatment plant
b. goes to creeks or rivers
c. goes to a landfill

2. More than 1/3 of what we throw away is:

a. glass
b. cheeseburgers
c. paper

3. The biggest cause of stormwater pollution is:

a. industries
b. people
c. your dog

4. Putting used motor oil in the trash or pouring it down the storm drain:

a. is usually safe
b. bothers Oscar the Grouch
c. can pollute creeks and rivers

5. Most of our garbage is:

a. buried in landfills
b. made in New York City
c. put into the ocean

6. When the label on a product says, "poisonous" or "toxic" you should:

a. burn it in the fireplace
b. take it to a household hazardous waste collection site
c. use it on your house plants

Answers: 1. b 2. c 3. b 4. c 5. a 6. b

Special thanks to the City of Portland, Bureau of Environmental Services

If you have any questions regarding the Stormwater Management Program please call the **City of Sacramento, Department of Utilities,** (916) 433-6369, or write 5770 Freeport Blvd., Suite 100, Sacramento, CA 95822.

LOVE LOUISIANA

Save a Lake! or a Bayou! or a Stream!

Ready to make a difference? It's as simple as deciding you want to clean up our waterways by educating others about the importance of not using our storm drains for dumping chemicals or other wastes. And you can begin by stenciling storm drains in your area in cooperation with the Department of Environmental Quality. **The Louisiana Storm Drain Stencil Program is part of DEQ's nonpoint source anti-pollution program.** Waste that comes out of a pipe is called "point source pollution". A nonpoint source of pollution refers to rainstorm run-off from various urban, agricultural or forestry sources. Two of the major sources of nonpoint source pollution are used motor oil and household cleaners dumped into storm drains. Our program involves stenciling a storm drain, or a sign near the drain, with a simple message: **DUMP NO WASTE, DRAINS TO LAKE** . . . or stream, or bayou. This simple message will be a reminder that storm drains are not garbage cans and should not be used for dumping because the water from these drains goes directly to our water sources untreated. Other communities, like those in Washington State, have found this a useful program in fighting unnecessary waste.

HOW TO JOIN

DEQ'S DRAIN STENCILING PROGRAM

Who is painting drains?

Community groups, boy scouts girl scouts, school groups, parents clubs, garden clubs, environmental groups, civic organizations, men and women, boys and girls, young and old, kids with class projects, adults providing community service.

How easy is getting permission?

Once you have mailed a volunteer form to DEQ, you will be notified about who to contact in your area for permission to stencil drains.

If you are painting drains along public thoroughfares, usually you will be directed to call your city or parish Public Works Department. Ask for the drain utility or road maintenance division.

You will then get a letter of approval from the public works department.

If the drains are located on private property, such as an apartment parking lot, get a letter of approval from the management.

What paints should be used?

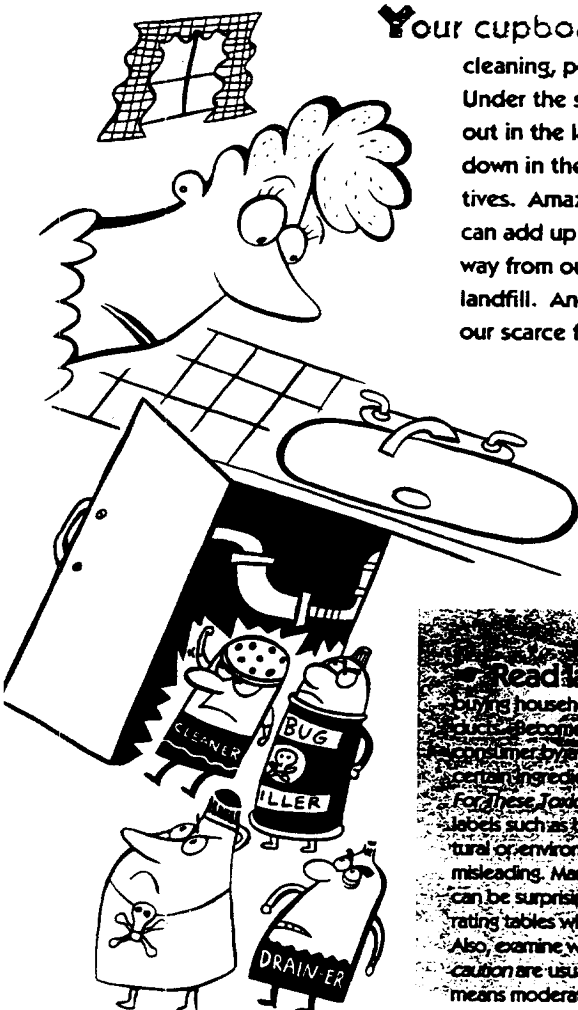
Suggested paints to be used are water-based, inverted tip marker, yellow traffic spray paints. An inverted tip can is more environmentally safe than aerosol cans because it is lead-free, contains no methylene chloride, it has lower volatile organic carbons and it is ozone-safe. One can of spray paint will stencil approximately 20 drains.

What other stenciling tips should be followed?

- Keep a record of storm drains completed on the stencil tracking form provided by DEQ.
- Make a record of drains you observe to be contaminated with wastes on your stencil tracking form. Have your project leader mail the tracking form to DEQ at the address listed in this brochure.
- Follow safety rules. Assign a traffic guard to wear a traffic vest. Do the project in groups.
- Wear old clothes and old, comfortable shoes.
- Clean up. Store the stencil in one plastic bag. Pick up all paper towels, rags or empty paint cans and dispose of in another bag. Dispose of all waste properly.
- Return the stencil, the stencil tracking form and paint cans to your project leader when finished.
- Maintain your drains and keep them free of debris.


estuarywise
100 tips on how you can prevent pollution of our bay and delta
I ♥ my
Estuary
Handbook for the San Francisco Bay-Delta Estuary

Inside Your Home



Your cupboards and closets contain dozens of everyday cleaning, polishing and painting products hazardous to our waterways. Under the sink lurk the drain openers, oven cleaners and insect sprays; out in the laundry room the chlorine bleaches and spot removers; down in the basement workshop the glues, paints and wood preservatives. Amazingly enough, these and other common household items can add up to a considerable source of pollution, once they find their way from our homes to the Estuary via drains, toilets and your local landfill. And don't forget that leaky faucet in the bathroom guzzling our scarce freshwater supply.

☛ **Read labels before** buying household cleaners and other products. Become an environmentally friendly consumer by avoiding products containing certain ingredients (see p. [illegible], *Watch Out For These Toxic Ingredients*). Be aware that labels such as biodegradable, organic, natural or environmentally friendly can be misleading. Many so called *green products* can be surprisingly toxic. Consult product rating tables whenever possible (see p. 32). Also, examine warnings. Products labeled *caution* are usually the least toxic, *warning* means moderate toxicity, and *danger*, *poison*, or the symbol of a skull and crossbones means it's extremely toxic.

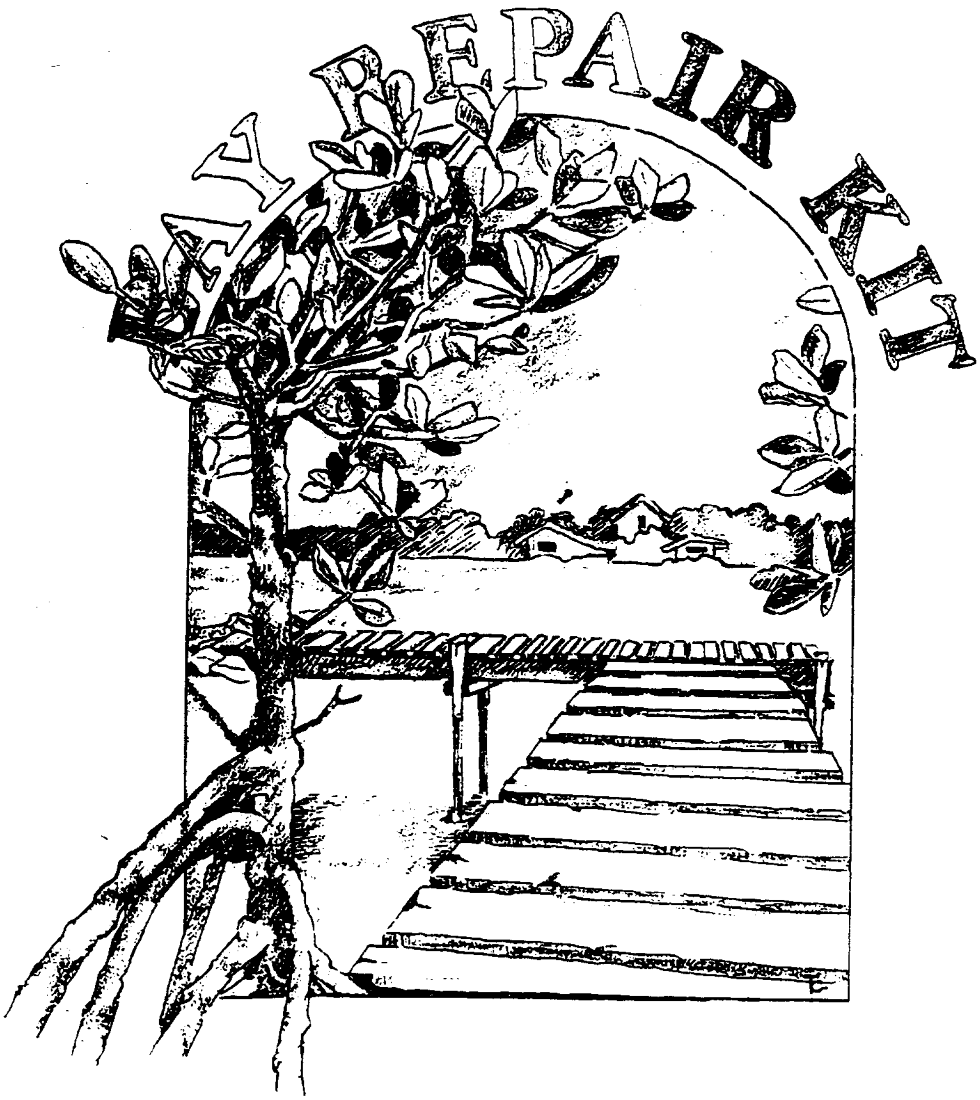
☛ **Use safe substitutes** [illegible]

☛ **Buy only as much** [illegible] Store [illegible] containers. [illegible]

☛ **Do not pour paints,** [illegible] preservatives, brush cleaners or solvents down the sink or toilet and never down storm drains. Clean up brushes and [illegible] buckets at the sink, not the gutter. [illegible]

Tackle it without toxics . . .

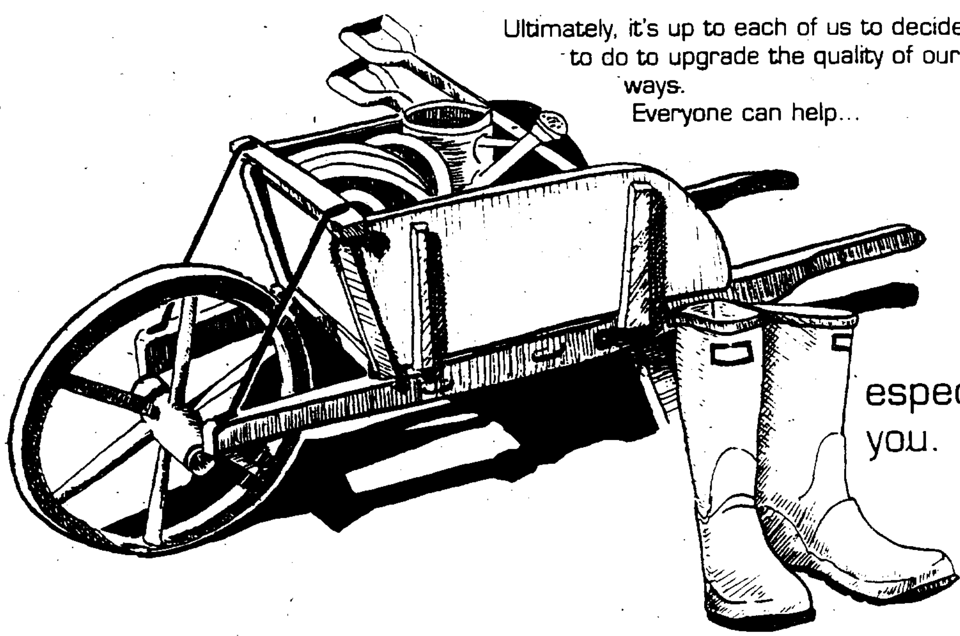
6


AY REPAIR KIT

Unknowingly, in the daily care of our households, we each may be polluting nearby bays and other waterways. This booklet offers practical steps to reduce that pollution in order to begin repairing our damaged coastal waters. Some suggestions are simple,cost-free,and require only a slight change of routine. Others are more intricate and car be implemented gradually over time. A few suggestions may even inspire you to re-landscape certain areas of your property.

Ultimately, it's up to each of us to decide what to do to upgrade the quality of our waterways.

Everyone can help...



especially you.

"Nobody ever made a greater mistake than he who did nothing because he thought he could only do a little."

Edmund Burke

R0026238

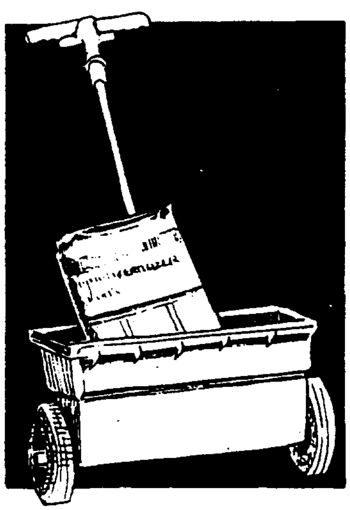
KEEP SURFACE RUNOFF CLEAN

Summertime • Late afternoon • Thunderstorms

Torrents of rain are pouring down onto your yard. It's virtually impossible to stop surface runoff now ...

The second line of defense is to **keep surface runoff clean**. The challenge is to prevent the runoff from picking up an array of contaminants from fertilizers, pesticides, bare ground, pets, pools, waste, cars and boats.

When fertilizing the lawn and landscape plants, remember the trade-off: the more you fertilize on land, the more you may be polluting the water.



Fertilizers

Fertilizers contain nitrogen and phosphorus, two elements which promote the growth of plants in water as well as land. Fertilizer-laden runoff can over-stimulate aquatic plant growth, causing algal blooms and fish kills.

AGENCY ADDRESSES AND PHONE NUMBERS

Sarasota County Natural Resources Department
Location: 1301 Cattlemen Road, Sarasota
Mailing address: P.O. Box 8, Sarasota, FL 34230

Coastal Zone Division	(813) 378-6113
Forestry Division	(813) 378-6115
South County office	(813) 493-4500
Natural Sciences Division	(813) 378-6113
Pollution Control Division	(813) 378-6128
Ecological Monitoring Division	(813) 378-6142

Sarasota County Solid Waste Management
8350 Bee Ridge Road
Sarasota, Florida 34241 (813) 951-5096

Sarasota County Cooperative Extension Service
2900 Ringling Blvd.
Sarasota, Florida 34237 (813) 951-4240

Sarasota County Environmental Library
7112 Curtiss Avenue
Sarasota, Florida 34231 (813) 924-9677

Manatee County Public Health Unit
410 6th Avenue East
Bradenton, Florida 34231 (813) 748-0666

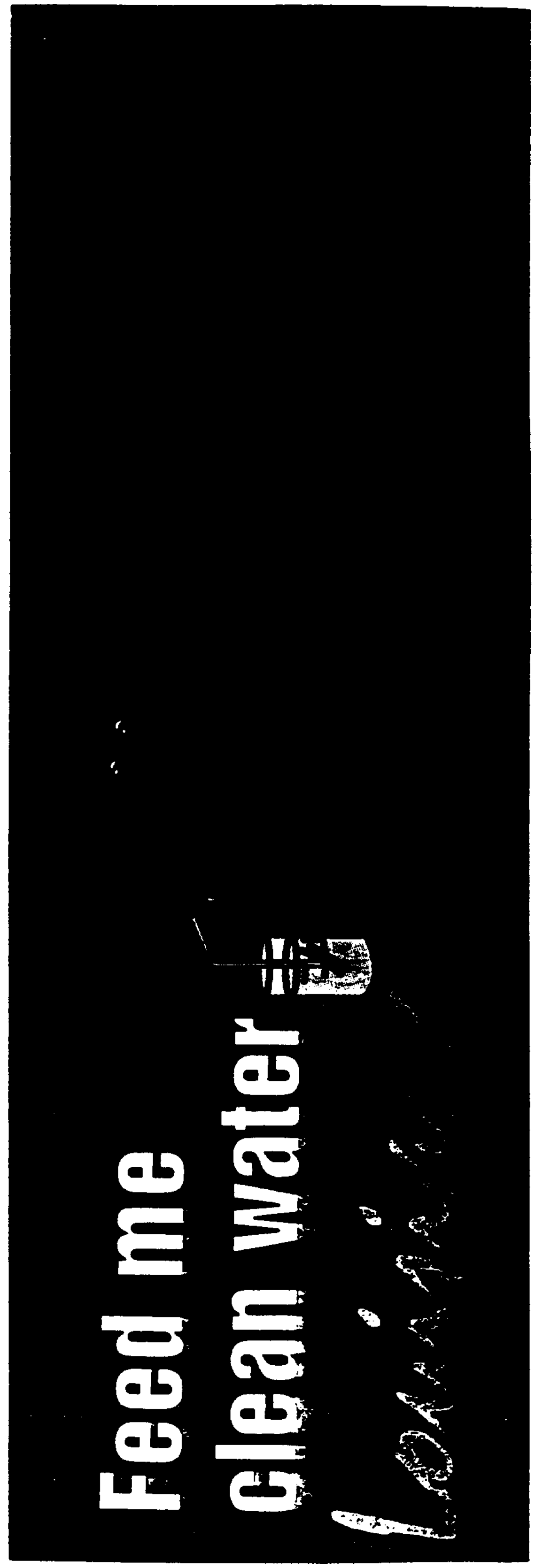
Pollution Control Division	ext. 1326
Environmental Health Division	ext. 1340

Manatee County Planning & Development Department
212 6th Avenue East
Bradenton, Florida 34231 (813) 746-3090

Manatee County Cooperative Extension Service
1303 17th Street West
Palmetto, Florida 34208 (813) 722-4524

National Estuary Program - Sarasota Bay Project

REGIONAL FLAVOR



R0026242

City of Phoenix
WATER SERVICES DEPARTMENT
Pollution Prevention Section
2303 West Durango
Phoenix, AZ 85009

WANTED

Your help is needed in locating the following notorious wastewater pollutants.

MERCURY

ARSENIC

And gang members Lead, Copper, Cyanide, Nickel, Cadmium, Zinc, Silver, Chromium, Beryllium, Thallium and Selenium.

City of Phoenix

WHAT CAN YOU DO

to arrest the use and hazardous disposal of these pollutants?

You can:

1 assess your industrial process to determine if any of these pollutants are present.

2 evaluate your industrial process to determine where you can reduce or eliminate the use of these pollutants.

3 contact your supplier and ask him to provide an alternate source of materials that does not contain harmful pollutants or heavy metals.

4 buy materials only as they are needed and in quantities which will be used before expiration dates.

5 schedule your production process so source materials are used effectively and efficiently.

6 institute a recycling program, either on or off site.

7 encourage your employees to identify ways to reduce or eliminate the use of these pollutants and heavy metals in your industrial process.

REWARD

By taking the steps recommended in this brochure, you will reduce the amount of pollutants and heavy metals you use in your production process and their disposal through the sewer. As a result, you will impress your customers, stockholders and boss by:

- saving your company money.
- reducing your company's potential environmental liabilities by avoiding costly lawsuits and/or penalties.
- displaying your company's environmental leadership by using waste-free processes and producing waste-free products.

- saving money for yourself, your business and your community by making it unnecessary for the city to install costly new equipment at its wastewater treatment plant, thereby keeping sewer rates reasonable.
- helping to keep our environment safe for you, your family and others to use, now and in the future.

For more information about preventing pollution at its source, contact:

Pollution Prevention Section
Water Services Department
City of Phoenix
2303 West Durango
Phoenix, AZ 85009
(602) 262-1859


I ♥ CREEKS

As Flo the Raccoon explains
to her boys Dwain and Rusty,

It's up to us
to keep pollution
out of storm drains!
What goes into the storm drains
(or street, or gutter) goes
right to our creeks and Bay.

If you see something dumped
or spilled near a storm drain,
call 329-2413 immediately!

Palo Alto Storm
Drain Program

415/321-2129

(Let's hope Rusty gets the message SOON!)

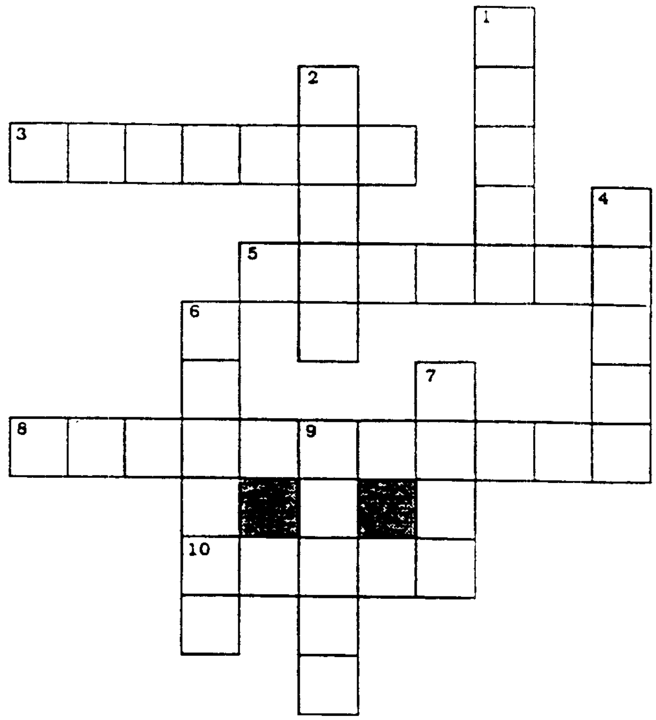
Printed on recycled paper, of course

R0026246

This activity book belongs to:

Water Wager: Have the Final Word

toxic
recycle
plastic
sludge
drain
glass
sewer
groundwater
cans
river



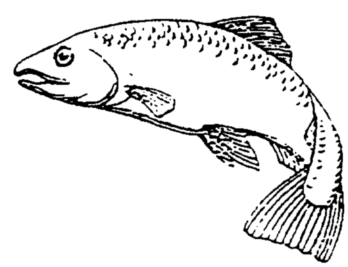
Across

3. A material sometimes made by humans that does not decompose and is very difficult to recycle.

5. What to do so that glass, aluminum and paper can be used again.

8. Water found in the earth.

10. A hard, breakable material which is good to recycle.



Down

1. Another word for poisonous.

2. A large stream that flows into a lake or ocean.

4. The pipe that carries wastewater to the treatment plant.

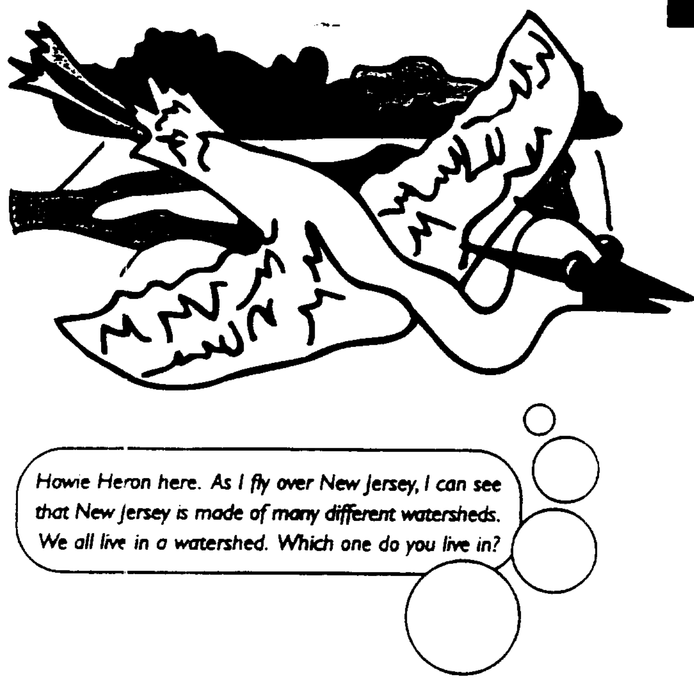
6. The name for the solid material that is taken out of treated water.

7. Another name for pop containers. (It's smart to recycle them).

9. Where the water goes down the sink or bathtub.

HOW TO BE A CLEAN WATER RAINGER

Save this booklet! It contains valuable information you can use!



WHAT IS A WATERSHED?

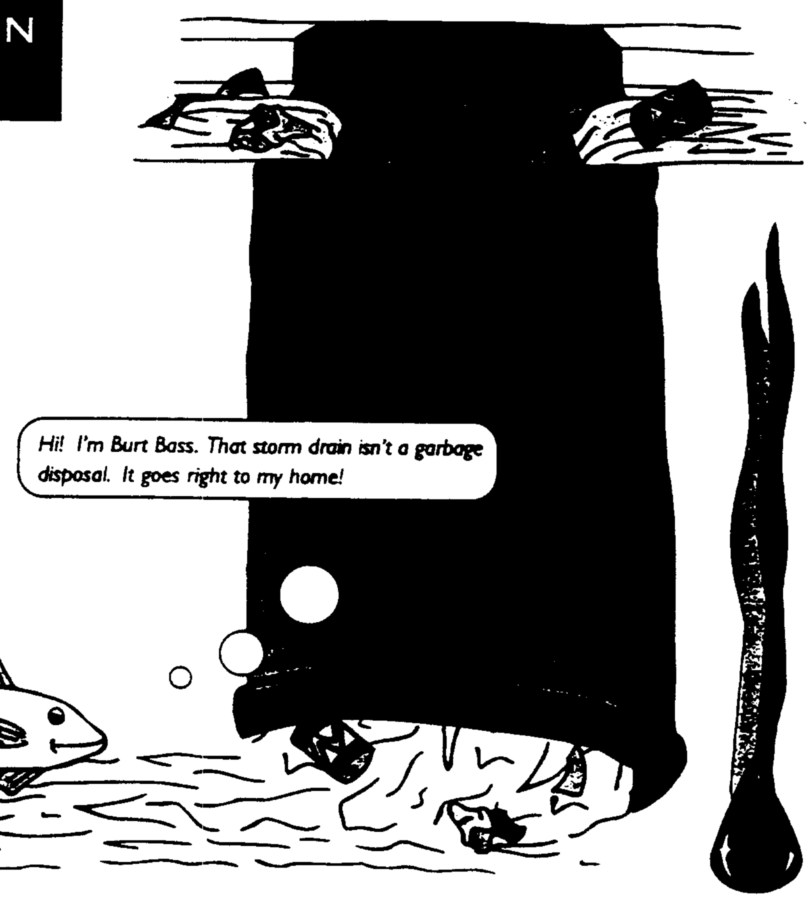
A watershed is the area of land surrounding a waterway that drains into it. A watershed includes not only the waterway itself but also the entire land area that drains to it. For example, the watershed of a lake would include not only the streams entering into that lake but also the land area that drains into those streams and eventually the lake.

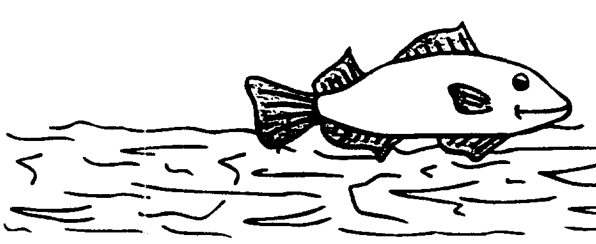
A watershed can be as small as a backyard that drains to a puddle or as large as the sections of New York, Pennsylvania, New Jersey and Delaware that drain into the Delaware River.

So what happens on the land in a watershed affects the waterway. For example if too many fertilizers are used on lawns, the extra fertilizer can end up in the local waterway. The same thing goes for ground water. The extra fertilizer could end up in ground water and maybe someone's well.

GET YOUR MIND IN THE GUTTER!

In urban and suburban parts of the state, manmade systems change the way water flows. Where does the water in the street gutter go? In most places in New Jersey, that gutter leads to a storm drain along the curb which goes directly to a local waterway. Whatever flows down the storm drain enters a series of underground pipes that lead to an outfall pipe that flows into a local waterway. The stormwater does not get treated. All the litter motor oil drippings, and other debris goes with it into the local waterway. That's why it's important to keep stormwater clean!

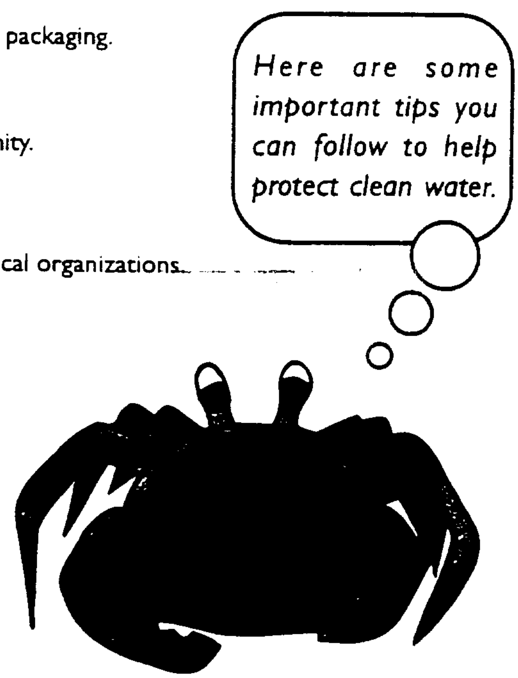




R0026250

TOP TEN THINGS YOU CAN DO TO HELP KEEP WATER CLEAN

- Never throw anything down storm drains. They are for rainwater only.
- Don't litter. Always put trash where it belongs.
- Always clean up after your pets. Obey your town's "pooper scooper" laws.
- Tell others how important it is to keep our land and water clean.
- Plant a tree. They take pollutants out of ground water, provide shade, and clean the air.
- Find out what waterway you live near. Where does your water come from?
- Precycle! Buy products that use the least amount of packaging.
- Recycle. Find out what is recyclable in your community. Buy products in recycled or recyclable containers.
- Learn about environmental issues. Get involved in local organizations.
- Conserve water whenever possible. For example, turn off the water while brushing your teeth and don't linger in the shower.



New Jersey Department of Environmental Protection
Office of Environmental [illegible] Floor
CN 418
Trenton, NJ 08625-0418
609-633-1179
Christine Todd Whitman, Governor
Robert C. Shinn, Jr., Commissioner

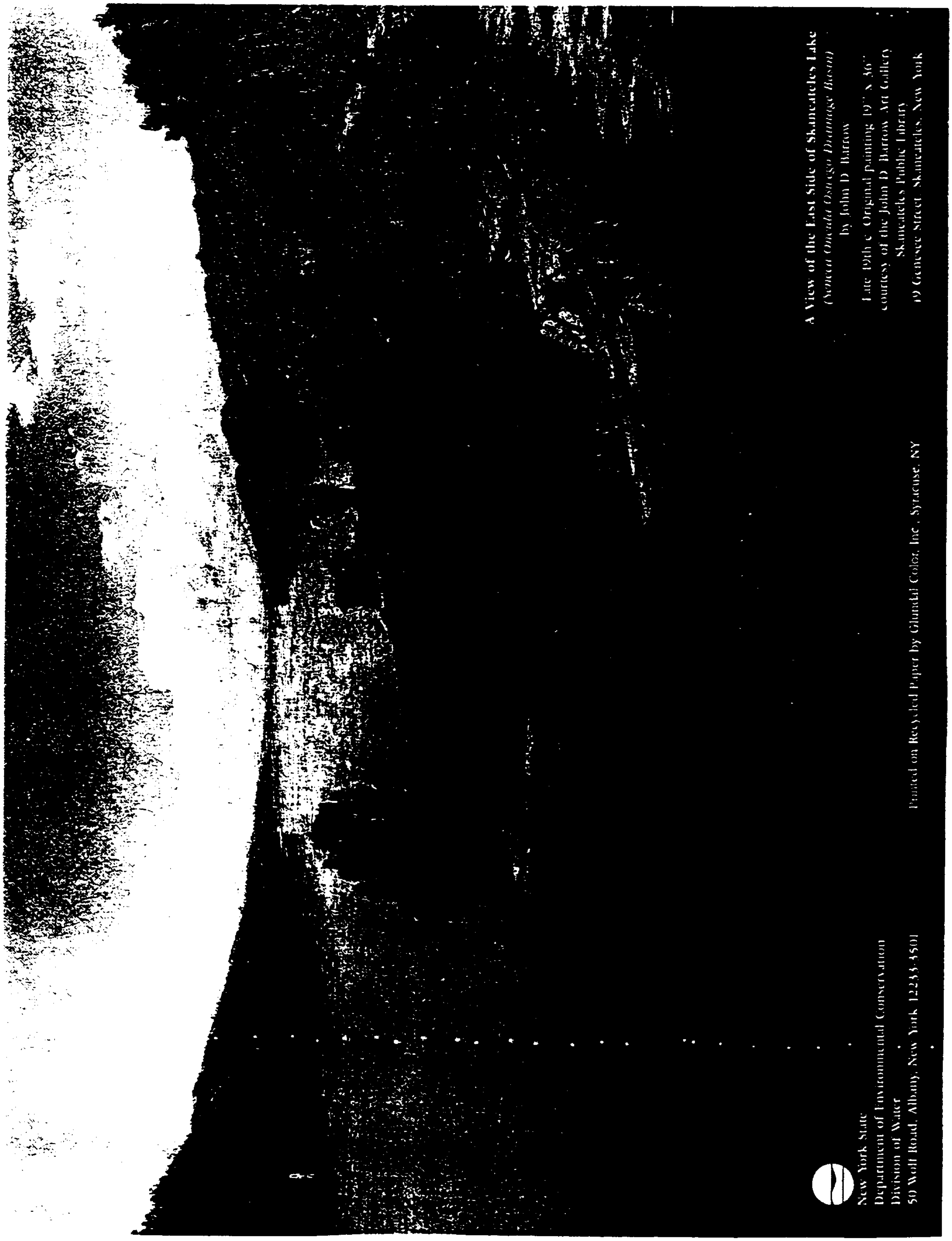
CLEAN WATER RAINGERS

new york state Watersheds

View of Storm King From the Hudson
(Lower Hudson River Drainage Basin)
by Francis Augustus Silva
Mid 19th c. Original painting 12" x 5 3/4"
from a private collection

New York State
Department of Environmental Conservation
Division of Water
50 Wolf Road, Albany, New York 12233-3501

Printed on Recycled Paper by Glundal Color, Inc., Syracuse, NY


A View of the East Side of Skaneateles Lake
(Seneca Oneida Oswego Drainage Basin)
by John D. Barrow
Late 19th c. Original painting 19" x 36"
courtesy of the John D. Barrow Art Gallery
Skaneateles Public Library
19 Genesee Street, Skaneateles, New York
New York State
Department of Environmental Conservation
Division of Water
50 Wolf Road, Albany, New York 12233-3501
Printed on Recycled Paper by Glundal Color, Inc., Syracuse, NY

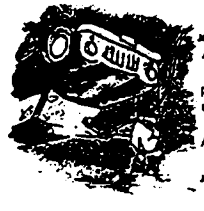
TARGETED POLLUTANTS AND ACTIVITIES

Plan your home maintenance projects to protect water quality

Here are some tips for protecting water quality, whether you do the work yourself or hire someone else. Remember, storm drains flow directly to our local creeks and on to San Francisco Bay!

Car Washing and Repair

If you do the work yourself:



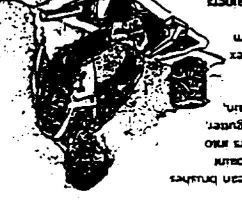
- Don't wash cars on a driveway or street where soapy water may flow to a storm drain. Wash on a lawn or unpaved surface. Dispose of leftover soapy water in a sink or toilet, not the street, driveway, or storm drain.
- If you change your own oil or antifreeze, recycle it! Never dump oil or any auto fluid onto the ground or into a storm drain or creek.
- Repair leaking vehicles promptly to help keep fluids off streets and out of storm drains. Soak up leaks and spills with an absorbent such as cat litter.

If you hire someone:

- Use a commercial car wash where water is recycled.
- Make sure mobile auto detailers use spill containment aids such as drop cloths when working in a street or driveway, and dispose of all wastewater in a sink, not the storm drain.
- Be sure your auto service center recycles oil and antifreeze, and follows shop cleanup practices that protect water quality.

Painting and Furniture Stripping

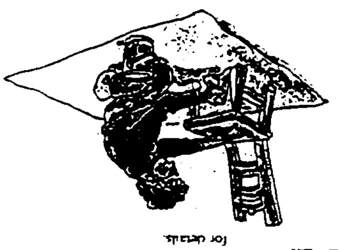
If you do the work yourself:



- Never clean brushes or rinse paint containers into a street, gutter, storm drain, or creek.
- Clean latex paint from brushes and containers in a sink. Filter, settle, and reuse thinners and solvents for oil-based paints.
- Dispose of unusable paints and thinners, thinner residue, and paint strippers through a household hazardous waste program.
- Empty, dry paint cans may go in household garbage, or they may be recycled in your city. Remove paint can lids before disposal.

If you hire someone:

- Make sure that painting contractors clean brushes and containers and dispose of paint residues properly — never in the street or storm drain.
- Professional painters must dispose of leftover paints and solvents as hazardous waste.
- Encourage your painter to use a special hazardous waste collection program for small businesses when it's available in your area. Call (408) 299-7300 for details.



Household hazardous waste collection

For information, contact your city's program or the Santa Clara County Household Hazardous Waste Program (408) 299-7300

City of Palo Alto (415) 496-6980
Drop-off first Sat. morning each month

City of Sunnyvale (408) 730-7278
Drop-off every 90 days; call for dates

City of Santa Clara (408) 984-3080
Drop-off twice a year

For a free 66-page booklet on less-toxic household products, call 800-794-2482

Curbside yard waste pickup

Contact your local recycling program or, in unincorporated areas of Santa Clara County, call (408) 441-1198

Curbside oil recycling programs

Campbell	(408) 354-2100
Cupertino	(408) 993-9440
Gilroy	(408) 848-0450
Los Altos	(415) 961-8040
Los Altos Hills	(415) 961-8040
Los Gatos	(408) 354-2100
Milpitas	(408) 432-0444
Monte Sereno	(408) 354-2100
Morgan Hill	(408) 779-7248
Mountain View	(415) 967-3034
Palo Alto	(415) 496-5910
San Jose	(408) 277-2700
Santa Clara	(408) 727-3044
Saratoga	(408) 354-2100
Sunnyvale	(408) 734-2330

Wastewater treatment plants

San Jose/Santa Clara Water Pollution Control Plant
(408) 945-5300

Sunnyvale Water Pollution Control Plant
(408) 730-7270

Palo Alto Regional Water Quality Control Plant
(415) 329-2598

If you see evidence of illegal dumping near or into a storm drain, call 911 immediately!

Printed on Recycled Paper

Santa Clara Valley
Nonpoint Source
Pollution Control Program

Home Maintenance Tips for a Cleaner Bay

Whether you do the work yourself or hire someone, you can help protect water quality

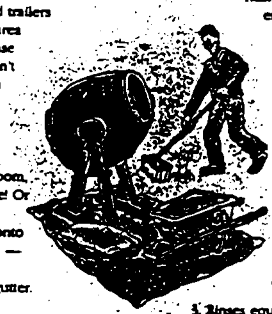
Santa Clara Valley
Nonpoint Source
Pollution Control Program

R0026256

Concrete, Masonry, and Asphalt Repair

If you do the work yourself:

- Set up and operate small mixers on heavy tarps or dropcloths.
- Hose down mixers, tools, and trailers in a dirt area where rinse water won't run into a creek or gutter.



- Clean up with a broom, not a hose! Or wash fine particles onto a dirt area — not into a street or gutter.
- Apply driveway sealants when no rain is forecast. Sweep first to prepare. Handle sealants with care and follow label directions.

If you hire someone:

- Explain to your concrete contractor that rinsing trucks or equipment in the street or near a storm drain endangers wildlife in our creeks and Bay — and it's illegal!

Make sure your concrete contractor:

1. Establishes a cleanup area before starting work.
2. Minimizes use of water in cleanup.
3. Rinses equipment onto an isolated dirt area, away from streets or creeks. Or, places a wheelbarrow under the chute and/or other equipment to catch rinsewater, and wheels it to a dirt area for disposal.
4. Rinses exposed aggregate concrete onto a dirt area.

Housecleaning and Window Washing

If you do the work yourself:

- Send dirty cleaning water down a sink or toilet, not into a street, gutter, or storm drain.

If you hire someone:

- Make sure people you hire understand that storm drains flow to the creeks and Bay with no treatment — so they won't dump anything into a storm drain.

Carpet/Upholstery Cleaning

If you do the work yourself:

- Dispose of dirty cleaning solution down a sink or toilet, not the storm drain.

If you hire someone:

- Ask professional carpet cleaners where they empty their tanks. Make sure they don't use the storm drain!
- Professionals should dispose of cleaning solutions down a sink or toilet, or return to their company for disposal to the sanitary sewer.

Pool/Spa Maintenance

If you do the work yourself:

- Control algae by regulating chlorine levels and by using a pool cover to block sunlight. Do NOT use copper-based algae control products.
- Always discharge pool or spa water to a sanitary sewer line cleanout. Never discharge pool or spa water to a creek, street, or storm drain. When it's time to empty your swimming pool, call your wastewater treatment plant for guidance. (See numbers on reverse.)
- Dispose of filter rinsewater and backwash into soil, not the gutter, creek, or storm drain. Or, call your wastewater treatment plant for guidance.

If you hire someone:

- Make sure your pool service contractor is not using copper products in your pool, and not disposing of filter backwash where it can run off to a storm drain.
- Make sure acid-wash rinsewater is neutralized before it is pumped to the sewer line cleanout. Call your wastewater treatment plant for guidance.

Lawn and Garden Care and Pest Control

If you do the work yourself:

- Don't use chemical pesticides or herbicides unless you have a major problem, and never in wet weather! Read labels carefully, and apply sparingly. Try to use products that are not hazardous to aquatic life.

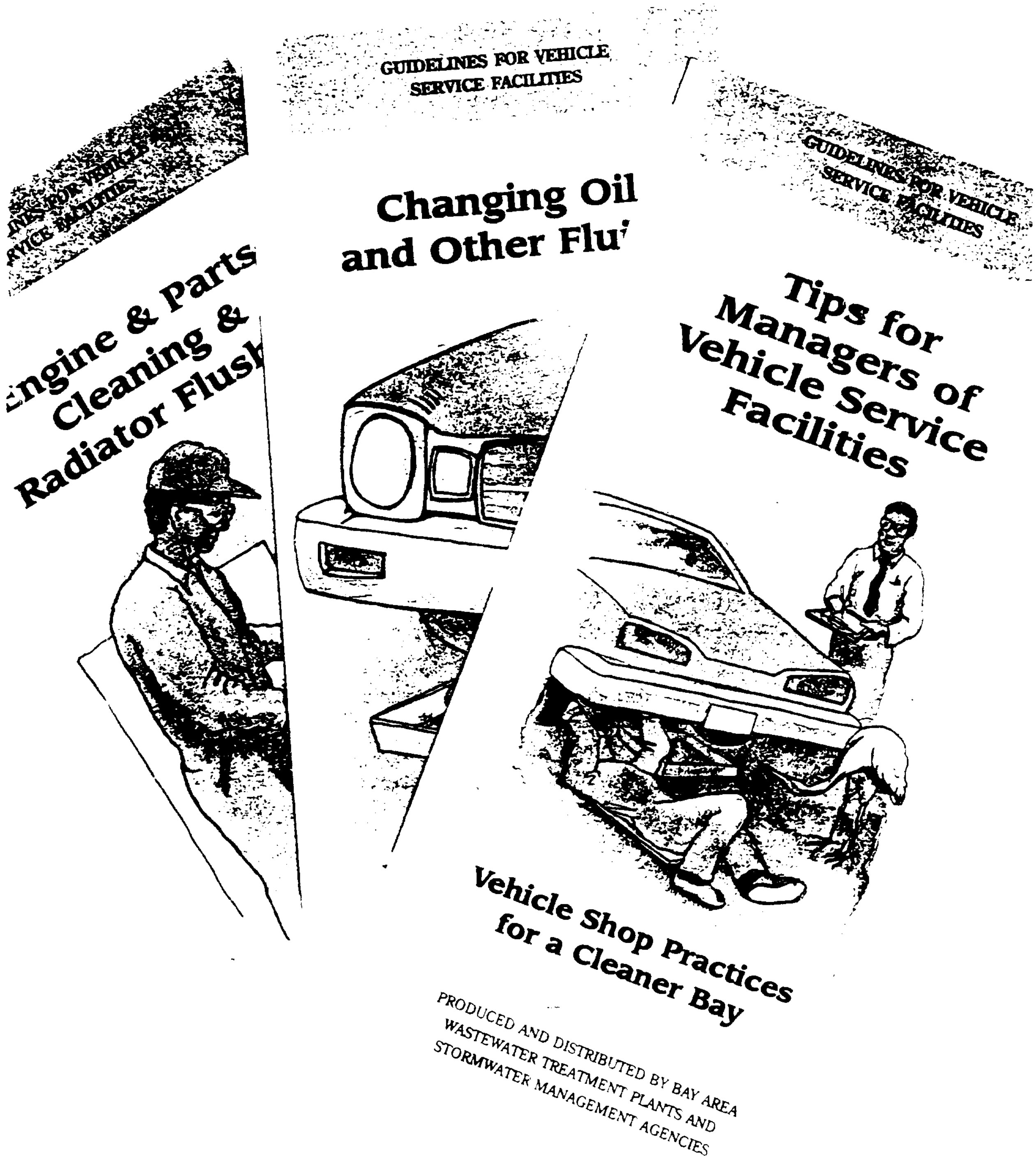
- Don't blow or rake yard waste into the street or gutter. Follow your community's guidelines for curbside yard waste pickup, or start your own compost pile.

- Sweep up the leaves and litter in the gutter in front of your property.
- If your city has yard waste pick-up, sweep up any residue left on the street after pick-up day.
- For information about maintaining a healthy, pest-free lawn, call the U.C. Cooperative Extension Office, (408) 299-2638.
- For a free copy of "Pests Bugging You?" a simple brochure about less-toxic pest control methods, call the Santa Clara Valley Nonpoint Source Pollution Control Program at (800) 794-2482.

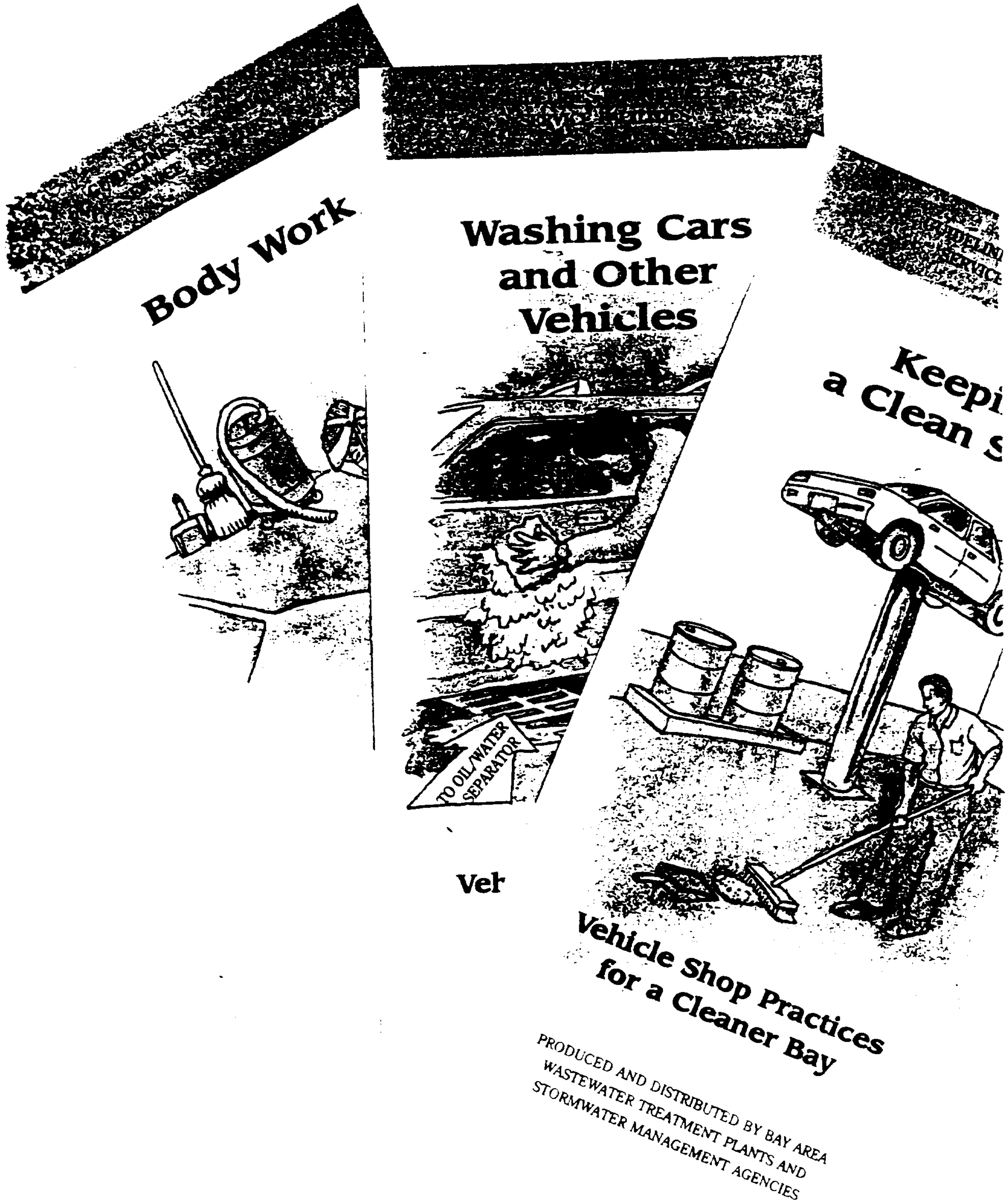
If you hire someone:

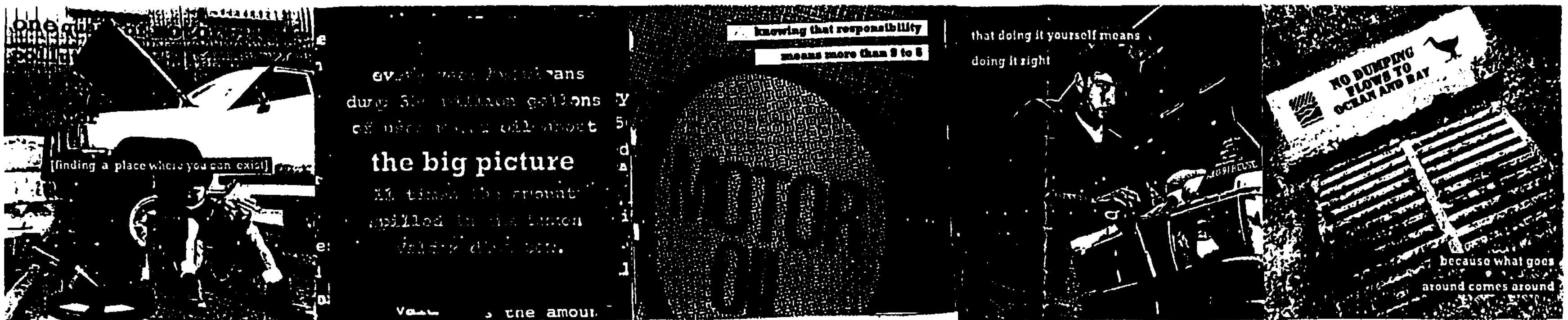
- Make sure your gardener does not blow or rake leaves into the street or gutter and collects yard waste for composting.
- If you contract with a lawn maintenance service, limit fertilizer applications to twice a year (fall and spring), and limit application of actual nitrogen on cool-season grasses to 4 lbs per 1,000 sq. feet. Chemical weed killers and other pesticides should not be necessary on a lawn that is appropriately watered, mowed, thatched, and aerated. Never apply chemicals when rain is forecast.

- Schedule excavation and grading projects for dry weather periods. Make sure your landscaper protects stockpiles and materials from wind and rain by storing them under secured sheeting or tarps.



GUIDELINES FOR VEHICLE
SERVICE FACILITIES
Changing Oil
and Other Flu
ngine & Parts
Cleaning &
Radiator Flus
GUIDELINES FOR VEHICLE
SERVICE FACILITIES
Tips for
Managers of
Vehicle Service
Facilities
Vehicle Shop Practices
for a Cleaner Bay
PRODUCED AND DISTRIBUTED BY BAY AREA
WASTEWATER TREATMENT PLANTS AND
STORMWATER MANAGEMENT AGENCIES


Body Work
Washing Cars and Other Vehicles
TO OIL/WATER SEPARATOR
Vehicle Shop Practices for a Cleaner Bay
PRODUCED AND DISTRIBUTED BY BAY AREA WASTEWATER TREATMENT PLANTS AND STORMWATER MANAGEMENT AGENCIES



If you like to change your oil yourself, make sure you finish the job right. Here's how:

1. Collect used oil in a clean, non breakable container that has a screw-on cap.
2. Don't mix other substances with your used oil such as paint, gasoline, solvents, or antifreeze. Your used oil must be free of contaminants in order to be recycled.
3. Mark "waste oil" on the container.
4. Place your used oil filter in a sealed plastic bag. Take it to a collection center that accepts oil filters.
5. Recycle your used oil by taking it to a used oil collection center. If your community has a curbside recycling program, place your used oil container on the curb.
6. Never dump used oil down the storm drain or in the gutter!

Recycling used oil is easy.
And it's **FREE!** Collection centers are popping up all over the County. To find out about convenient locations near you, call:

Reciclar aceite gastado es fácil y **¡GRATIS!** Se encuentran centros de colección en todo el Condado. Para más información sobre el centro de colección más cercano llame al teléfono:

1-800-94REUSE

This number will also provide you with information about disposal of household hazardous waste and stormwater pollution prevention.

This information is brought to you by:

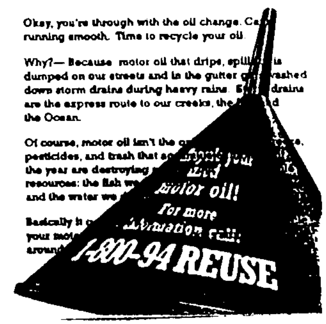
PARTNERS IN PREVENTING WATER POLLUTION

Okay, you're through with the oil change. Ca[r] running smooth. Time to recycle your oil.

Why?— Because motor oil that drips, spill[s] is dumped on our streets and in the gutter [is] washed down storm drains during heavy rains. [Storm] drains are the express route to our creeks, the [Bay an]d the Ocean.

Of course, motor oil isn't the o[nly] ... pesticides, and trash that ... the year are destroying ... resources: the fish w... and the water we ...

Basically it ... your mot... around ...



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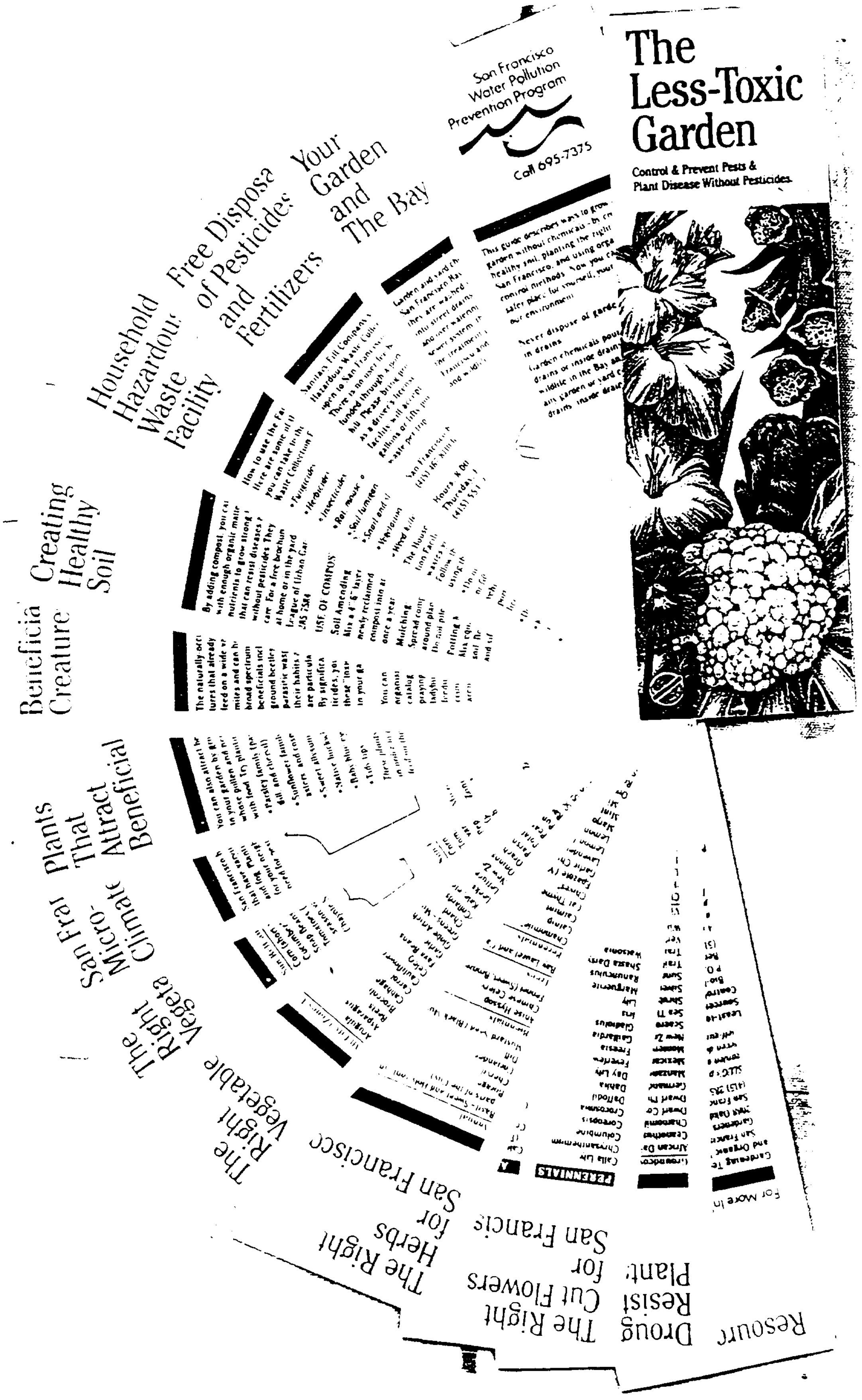
The Less-Toxic Garden
Control & Prevent Pests & Plant Disease Without Pesticides.
San Francisco Water Pollution Prevention Program
Call 695-7375
Your Garden and The Bay
Free Disposa of Pesticides and Fertilizers
Household Hazardous Waste Facility
Creating Healthy Soil
Beneficia Creature
Plants That Attract Beneficial
San Fra Micro-Climate
The Right Vegeta
The Right Vegetable for San Francisco
The Right Herbs for San Francisco
The Right Cut Flowers for San Francis
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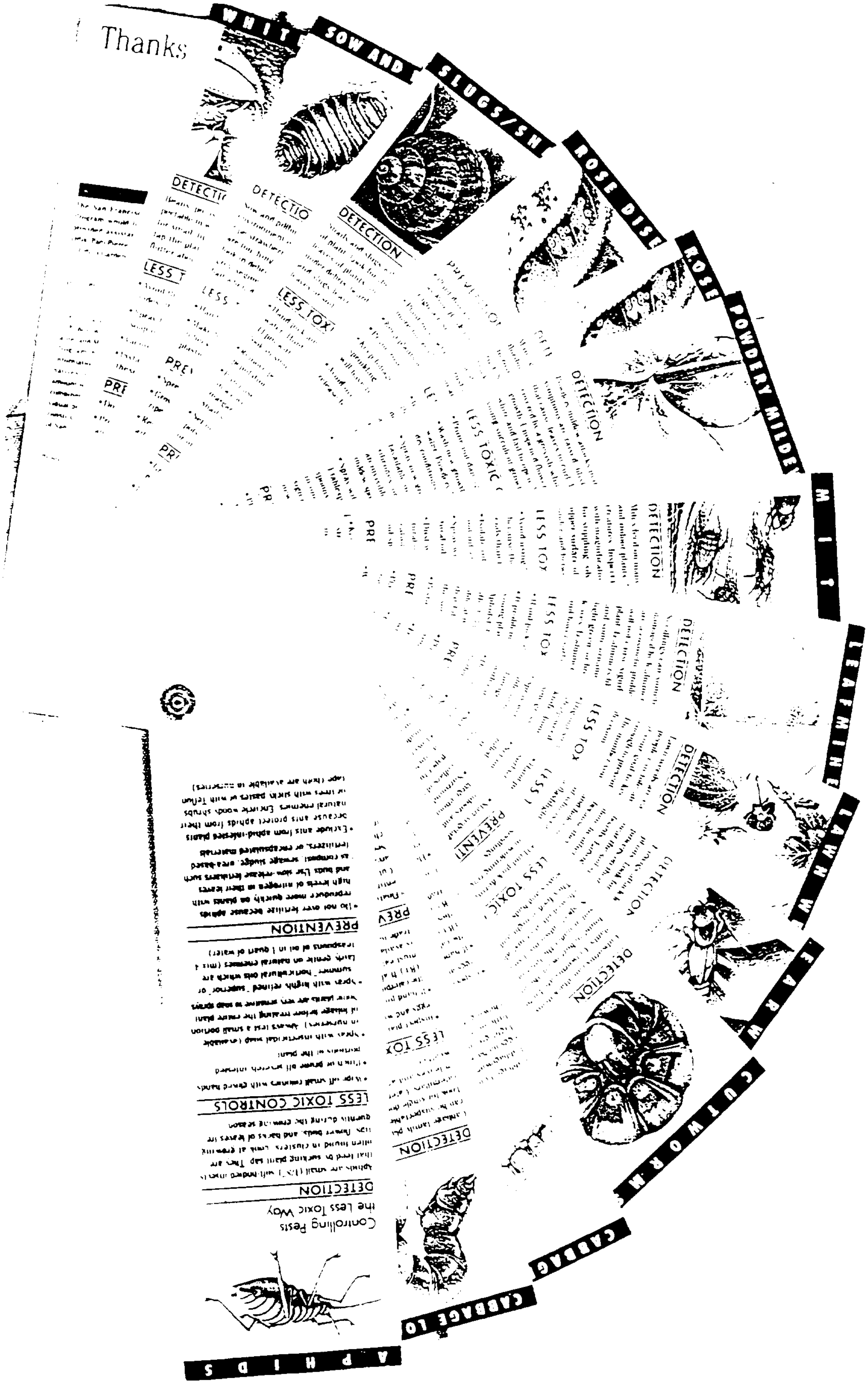
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APHIDS
Controlling Pests the Less Toxic Way
DETECTION
LESS TOXIC CONTROLS
PREVENTION

Pollution From Surface Cleaning

It harms the environment . . .

In most parts of the San Francisco Bay Area, storm drains are pathways for pollution, traveling directly from streets, gutters, and other paved surfaces to local creeks or the Bay, Ocean or Delta. Wash water from surface cleaning activities often carries pollutants that can harm the numerous wildlife species that depend on healthy waterways for their survival.

. . .And it's against the law!

Allowing polluting substances into storm drains is prohibited in California. Both the person who discharges the pollutant or leaves it behind, and the owner of the property where the material is generated are liable.

This folder provides guidance for mobile cleaners to prevent pollution when cleaning flat surfaces such as sidewalks, plazas, building exteriors, parking areas, and drive-throughs.

This guidance is not specifically intended to be appropriate for other mobile cleaning jobs such as fleet washing and detailing, carpet cleaning, or cleaning of food-related equipment.

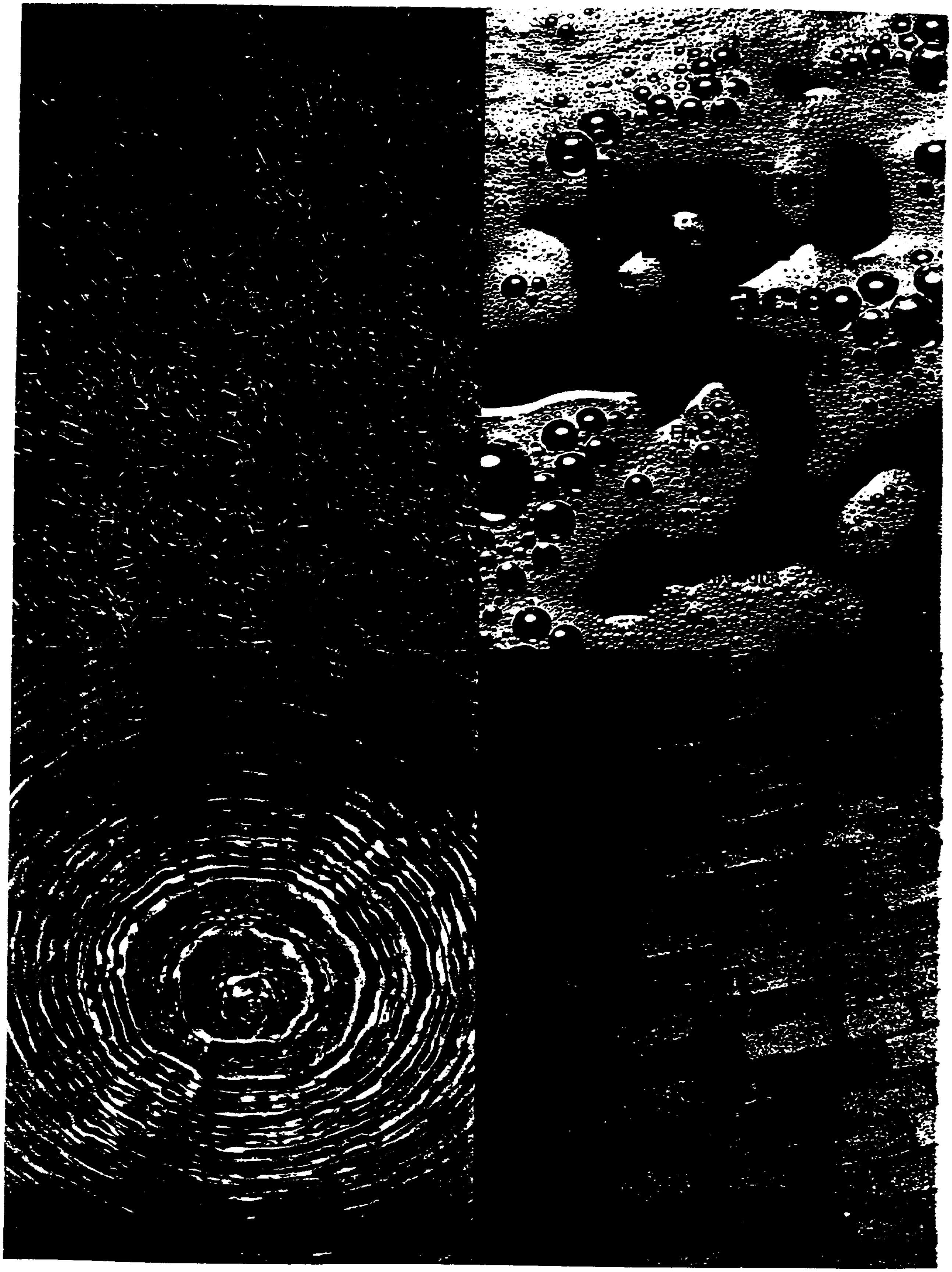
Where do these pollutants come from?

In general, three phases of the cleaning process can cause problems for the environment:

- Using harmful cleaning chemicals—including soaps as well as solvents
- Removing toxic materials such as oil, antifreeze, and grease from parking lots, sidewalks, or other surfaces
- Generating polluted wash water from activities such as wet sand blasting of buildings to remove paint

What sorts of hazardous waste can surface cleaning generate?

- Oil-saturated absorbents (but not oil-saturated rags, which can be cleaned at an industrial laundry)
- Wash water that contains lead paint chips
- Solvent cleaners



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So Where Should Wash Water Go?

Onto landscaping or unpaved surface

Wash water from cleaning unpainted building exteriors, sidewalks, or plazas, if:

- Discharge does not contain hazardous waste

AND

- Discharge will not cause flooding or nuisance problems, or flow to a creek

AND

- You have the owner's permission

Down a sink, toilet, or cleanout — through the sewer to a wastewater treatment plant

Wash water from surface cleaning of painted building exteriors, sidewalks, plazas, parking areas, drive-throughs, food service facility dumpster/grease containment areas, etc., if:

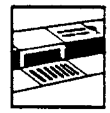
- You have used dry cleanup methods before washing with or without soap

AND

- Discharge does not contain hazardous waste

AND

- (For parking lots, traffic areas, food service facility dumpster/grease containment areas) You or the property owner have checked the local wastewater treatment plant's requirements before discharging to the sewer



To the street or storm drain

Wash water from cleaning sidewalks, plazas, and building exteriors, if:

- You have *successfully* used dry cleanup methods (described in the "tips" section of this folder to remove fresh oil stains, debris, and similar pollutants—before using water

AND

- Cleaning is done with water only—no soap or other cleaning chemicals

AND

- Water has not removed paint

Tips on proper cleaning and disposal methods

Avoid using soap!

- Even biodegradable soap is harmful to the environment. Before you use soap, test to see whether hot water under pressure will do the job.

Dry cleanup methods

- In many cases you can eliminate the need to collect and/or divert wash water if you follow this two-step process:
  1. Use absorbents (such as rags, absorbent mats or pads, rice hull ash, cat litter, vermiculite, or sand) to pick up greasy or oily spills.
  2. Sweep or vacuum to pick up litter, debris, or saturated absorbents
- Waste materials from dry cleanup such as absorbents, paint chips, etc. may often be disposed of in the trash. Check with the local solid waste authority to be sure. Rags may be sent to an industrial laundry.

Screening wash water

- When cleaning surfaces such as buildings and decks without loose paint, sidewalks, or plazas *without soap*, thorough dry cleanup should be sufficient to protect storm drains. However if any debris could enter storm drains or remain in the gutter or street after cleaning, wash water should first pass through a "20 mesh" or finer screen to catch the material, which should be disposed of in the trash

Collecting wash water

- A simple and acceptable method for collecting wash water on private property requires only a drain plug, small sump pump, and a length of hose. If a small parking-lot-type catch basin is available, remove the grate, plug the drain pipe (usually 2, 3, or 4 inches in diameter), and place the pump in the catch basin, attached to a garden hose. As wash water drains to this lowest spot, pump to landscaping, a sewer line cleanout, or a container for later disposal to the sewer.
- Vacuum booms are another option for capturing and collecting wash water.

Directing wash water to landscaping

- When routing wash water to landscaping, check the slope and area to be sure to avoid runoff into a street or gutter. If the soil is very dry, wet it down thoroughly before discharging so that wash water will soak into the soil instead of running off to the street, gutter, or storm drain.

Blocking storm drains or containing wash water

- Sand bags can be used to create a barrier around storm drains.
- Plugs or rubber mats can be used to seal storm drain openings.
- You can also use vacuum booms, containment pads, or temporary berms to keep wash water away from the street, gutter, or storm drain.

Hazardous waste disposal

- Be sure to read cleaning product labels before disposing of wash water. Follow use and disposal instructions carefully.
- Check with the city or county environmental health department to find out how small businesses can dispose of hazardous waste at a drop-off event (instead of hiring a hazardous waste hauler). In general, you must generate less than 27 gallons or 220 pounds of a particular type of waste each month to qualify to use these "Conditionally Exempt Small Quantity Generator" (CESQG) programs.

Equipment and supplies

- Special materials such as sheets of absorbent, storm drain plugs and seals, small sump pumps, and vacuum booms are available from many vendors. For more information check catalogs such as Pigalog (800-468-4647), Lab Safety Supply (800-356-0783), C&H (800-558-9966), and W.W. Grainger (408-433-9889), or call the Cleaning Equipment Trade Association (800-433-9889) or the Power Washers of North America (202-393-7044).

Remember, sending water that contains soap or any other type of pollution to a storm drain or water body violates state and/or local regulations!

Cleaning and Disposal

Type of Surface	Cleaning Method	Proper Disposal
Sidewalks, plazas	Dry cleanup* first, **wash without soap**	Screen wash water,* if needed, to catch debris THEN Discharge to landscaping,* or to a gutter, street, or storm drain
Sidewalks, plazas	Block the storm drain or contain runoff* Dry cleanup,* then wash **with soap***	Discharge to landscaping* OR Collect water and pump to the sewer*
Parking areas, driveways, drive-throughs	1. Block the storm drain or contain runoff* 2. Use absorbents to pick up oil; then dry sweep 3. Clean with or without soap	Collect water and pump to the sewer* *Check the local wastewater authority's requirements for discharge*
Restaurant/food handling dumpster areas, grease storage	Block the storm drain or contain runoff* Dry cleanup	If you must use water after sweeping/using absorbents, collect water and pump to the sewer* *Check the local wastewater authority's requirements for discharge*
Building surfaces, decks, etc., without loose paint	Use high-pressure water, no soap	Screen wash water,* if needed, to catch debris THEN Discharge to landscaping,* or to a gutter, street, or storm drain
Unpainted building surfaces, wood decks, etc.	Block the storm drain or contain runoff* Use soap or acid wash to remove deposits, wood restorer, or other chemicals	Make sure pH is between 6 and 10 THEN Discharge to landscaping* OR Collect wash water in a tank* and pump to the sewer *Check the local wastewater authority's requirements for discharge*
Painted surfaces being cleaned to remove paint or graffiti	Block the storm drain or contain runoff* Use any cleaning method	Collect wash water in a tank and pump to the sewer, or dispose as hazardous waste, as appropriate* *Call the local wastewater authority or the state Department of Toxic Substances Control (510-540-3732) for help in determining whether the paint contains toxic pollutants such as lead, mercury, or tri-butyl tin; or if the solvent cleaners you use are hazardous*
Graffiti removal	Block the storm drain or contain runoff* Wet sand-blast	Direct all runoff to a landscaped or unpaved area* OR Follow instructions above for painted surfaces

* *See tips section for ideas on how to do this!*

Pollution Prevention Voucher

____(cleaner company name), cleaner of the premises described below, has been trained by the Bay Area Stormwater Management Agencies Association in proper surface cleaning techniques for water pollution prevention.

Customer company name______________________Address______________________

Check all that apply:

Surface(s) cleaned	**Cleaning method**	**Precautions**	**Wash water disposal**
____Building exterior	____Water only	____Dry cleanup (sweeping, absorbents)	____Landscaping/ unpaved area
____Sidewalks, plazas	____Water and soap	____Block storm drain	____Gutter, street, storm drain
____Parking area/ drive-throughs	____Acid wash	____Runoff____contained	____Sanitary sewer
____Dumpster area/ grease storage	____Other chemicals (list)__________ __________	____screened	____Hazardous waste disposal
____Paint/graffiti removal	____Wet sand blast	____collected	____Other (describe) __________
____Other (describe) __________	____Other (describe) __________	____pH adjusted	
		____Other (describe) __________	

Cleaner's signature______________________Phone__________Date__________

Customer's signature______________________Customer's name (print)______________________

Allowing polluting substances into storm drains is prohibited in California. Both the person who discharges the pollutant or leaves it behind, and the owner of the property where the material is generated are liable.

PINK - CUSTOMER COPY WHITE - OFFICE COPY

We'll do the Job Right!

______________ is a Recognized Mobile Cleaner trained to prevent pollution of local creeks, the Bay, and Delta.

Cleaning water from

- Sidewalks
- Plazas
- Dumpster areas
- Building exteriors
- Parking areas/drive-throughs

pollutes our waterways when allowed to reach a creek or storm drain. Storm drain pollution is against the law in California. Liability is shared by the property owner and the actual discharger.

We've been trained to *Do the Job Right*. When we're finished, we'll provide you with a voucher declaring that your premises have been cleaned by a Recognized Mobile Cleaner.

Ask us about:

- Using dry cleanup methods before washing
- Blocking storm drains to protect them from pollution
- Directing wash water to landscaping if acceptable

Recognized by the Bay Area Stormwater Management Agencies Association and the San Francisco Bay Regional Water Quality Control Board.

For more information, call 510/286-0615.

CITYSCOPE

DIAZINON USE DISCOURAGED

The problem is not going away! Tests of Greenville's wastewater still show toxic levels of the pesticide diazinon. Unfortunately, an efficient, cost-effective method of removing the pesticide from water has not yet been developed. If diazinon continues to contaminate our wastewater, Greenville water utility customers will face major increases in their sewer bills to correct the problem.

The pesticide use survey conducted earlier this year showed widespread use of diazinon in the city. Even when applied properly, diazinon and other pesticides can still make their way into the wastewater system. Since even trace amounts are toxic to the test organisms it appears that proper usage isn't effective in controlling the contamination.

The only *guaranteed* way to co rect the water toxicity problem for all Greenville residents to st *using diazinon* and to decrease th use of other synthetic pesticides. less toxic, environmentally sour pest management program c control insect pests without creati dangerous residues which can co taminate wastewater or groun water.

The Office of Public Education : Water Utilities and the W. Walwor Harrison Public Library have join forces to provide residents wi information on such pest-ma agement programs.

Some of the books available at t library include ***Tiny Game Huntin*** *Environmentally Healthy Ways Trap and Kill Pests in Your Hou and Garden,* ***The Encyclopedia Natural Insect and Disease Contr*** *Dr. Pitcairn's* ***Complete Guide Natural Health for Dogs and Ca Rodale's Chemical-Free Yard an Garden,*** J. Howard Garrett's ***Orga Gardening*** and ***Plants of t. Metroplex III*** and ***Safety at Hon*** *A Guide to the Hazards of Lawn a Garden Pesticides and Safer Ways Manage Pests.*

For more information on the books and others about enviro mentally safe pest control, vi the Harrison Library at 3716 I Street, or contact the Office Public Education for Water Utilit at 457-3149.

A-8—Greenville Herald Banner, Sunday, April 10, 1994

Free seminar on fire ant control planned Tuesday

Fire ant control will the be topic of a special program Tuesday, sponsored by the Public Education for Greenville Water Utilities and the Hunt County Agriculture Extension Service.

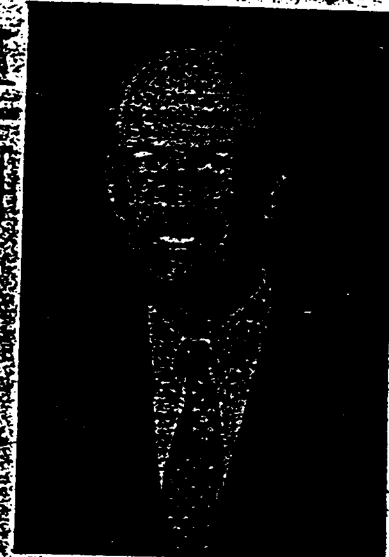
The public seminar will begin at 7 p.m. at Crestview Christian Church, 5605 Wesley.

Dr. Michael Merchant, Texas Agriculture Extension Urban Entomologist will be on hand to describe the two-step method for fire ant control. Developed by the Texas Agriculture Extension Service, this method combines the broadcast application of a bait and treatment of individual mounds for effective fire ant control.

The Two-Step Method shows much promise, according to JoAnn Hall and Anita Mitchell, coordinators for the city's Public Education program. In 1993, volunteers from six counties in north central Texas participated in an evaluation of the method.

A survey of these volunteers found that 79 percent were satisfied or very satisfied with the level of fire ant control with the Two-Step Method, that 80 percent obtained better control than they had with the other methods tried in the past, and 84 percent planned to continue using the Two-Step Method.

Persons unable to attend the seminar but would like to receive information on the Two-Step Method should call Public Education for Greenville Water Utilities at 457-3149, or the Hunt County Extension Service at 455-4203.



Mike Merchant

R0026270

Community

Seminar to help fight pesky critters

By JoAnn Hall, Anita Mitchell
Special to the Herald Banner

Free
Flea & Tick Seminar
Thursday, July 7 at 7:00 p.m.
Fletcher Warren Civic Center

CLEAN GREENVILLE INC

Chances are, if you've got a pet, you've got fleas or ticks.

Our recent warm, humid weather has been ideal for the breeding of large flea and tick populations.

In an effort to provide area residents with the latest flea and tick control information, a free seminar will be sponsored by Public Education for Greenville Water Utilities and the Hunt County Extension Service on Thursday.

The public seminar will begin at 7 p.m. at the Fletcher Warren Civic Center, 5501 Hwy. 69.

Dr. Mike Merchant, Texas Agricultural Extension Urban Entomologist, will be the featured speaker. His presentation will cover indoor/outdoor flea and tick control as well as on-pet treatment.

Several local veterinarians and retailers will also be present to provide information on locally available products for flea and tick control.

Area residents who have been experiencing flea and tick infestations are encouraged to attend this free seminar.

No advanced registration is required.

For additional information on Thursday's seminar call Public Education for Greenville Water Utilities at 457-3149.

Hall and Mitchell are coordinators of Public Education for Greenville Water Utilities.

Community

A-2--Greenville Herald Banner, Monday, January 23, 1995

There are ways to control pests

By JoAnn Hall
and Anita Mitchell

There's an old saying that the only things that can't be avoided in life are death and taxes. This should probably be amended to include cockroaches. Cockroaches have been pestering humankind since Roman times. For many, the battle against cockroach invasions is never-ending. And a trip to the store to select a cockroach control product may only add to one's frustration.

A recent article in "Common Sense Pest Control Quarterly" provides invaluable information to those seeking relief from cockroach infestations.

Start by practicing cockroach prevention. Properly store food and keep dishes and food preparation areas clean. Take household trash out every day and use a trash can with a tight-fitting lid. Block insect entry points by screening windows and vents. Caulk or paint cracks or crevices and weatherstrip doors.

If cockroaches have already moved in, boric acid is a very effective control product. Place boric acid in and around cracks and crevices in areas where roaches have been sighted.

PUBLIC EDUCATION
Greenville Water Utilities
(903) 457-3149

Other locations for application are under kitchen appliances and around plumbing fixtures and pipes. Observe these safety precautions when working with boric acid: do not place it where children and pets can get into it, and wear goggles and gloves when applying.

Another effective control method is the use of bait stations. Bait stations are safe and easy to use. The control agent is housed in a small plastic disk that allows the cockroaches in, but blocks human and animal contact. Because cockroaches like to explore tight spaces, bait stations are very attractive to them.

Select bait stations that contain hydramethylnon as the active ingredient. Place bait stations near favorite roach hang-outs such as under the kitchen sink, behind or under the refrigerator and stove, in upper and lower kitchen cabinets, and in the bathroom behind the toilet and under the sink.

Not all bait stations contain the same amount of bait so consider placing two stations in each of these areas to provide greater control. Make sure the stations are positioned against the wall so that roaches will encounter them as part of their daily activities.

CLEAN GREENVILLE INC

Follow the manufacturer's recommendations for replacement and disposal.

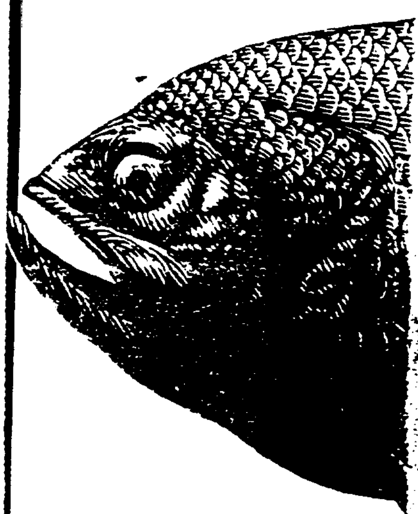
Additional information on cockroach control is available from the Office of Public Education for Greenville Water Utilities at 457-3149. And remember, don't use Diazinon!

Hall and Mitchell are coordinators of Public Education for Greenville Water Utilities.

Good Practices To Protect Our Creeks And Bay

Guidelines for

- Restaurants
- Grocery Stores
- Cafeterias
- Bakeries
- Delicatessens



Contents

Guidelines for Food Handling Facilities 2

Types of Pollution and Sewer or Storm Drain? 3

Cleaning Equipment 4

Grease Handling/Disposal 5

Spill Cleanup and Pavement Cleaning 6

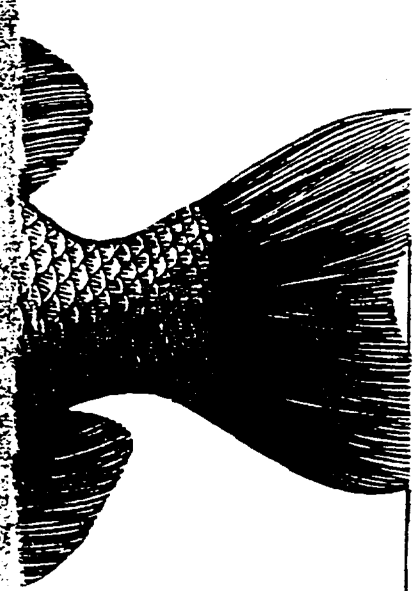
Dumpster and Loading Dock Areas 7

Training Employees 8

Employee Training Guidelines 9

Worksheet for Water Quality Protection 10

Numbers to Call for More Information 12



GUIDELINES FOR FOOD HANDLING FACILITIES

In the Santa Clara Valley, all storm drains flow directly to local creeks and the San Francisco Bay, with no treatment. Stormwater pollution is a serious problem for wildlife dependent on our waterways, and for the people who live near polluted streams or baylands.

Food handling facilities such as restaurants, institutional cafeterias, grocery stores, bakeries, and delis, contribute to this stormwater pollution mainly through improper cleanup practices that allow food particles, oil, grease, and cleaning products to flow into a street, gutter, or storm drain.

All of the cities in the Valley are required by the Regional Water Quality Control Board to enforce local ordinances prohibiting the discharge of pollutants to storm drains or local creeks. Also, the California Department of Fish and Game forbids any discharge of materials that could pass into creeks, rivers, or the Bay that would be "deleterious to fish, plant life, or bird life."

In addition, the Santa Clara County Department of Environmental Health and local wastewater treatment plants require that all grease traps and other grease removal devices be cleaned as often as necessary to prevent overflow and to meet local grease and oil limits in wastewater. Check with these agencies to find out about other requirements — see phone numbers on page 12.

Following the practices in this manual will ensure compliance with ordinance requirements with respect to both the sanitary sewer and the storm drains, and will help contribute to a cleaner Bay. Please share this information with any contractors that you hire.


你是否知道任何
你的餐廳或商店
後門，或者是
垃圾場及停車
出的物體，最
流入陰溝、
上的溝渠，
經任何處理
往附近的溪
讓我們保
健康!請
良好的
NHỮNG
CHÙI R
DỂ B
SUỐ
VÀ
C
RECOMENDACIO
DE LIMPIEZA
PROTEGER
TROS RIAC
Y NUEST
GOOD CLEANING
PRACTICES TO
PROTECT OUR
CREEKS AND BAY
TO AID
YOU MAY WISH TO
PHOTO
FOR ADDITIONAL COPIES OF
SANTA CLARA VALLEY
NONPOINT SOURCE

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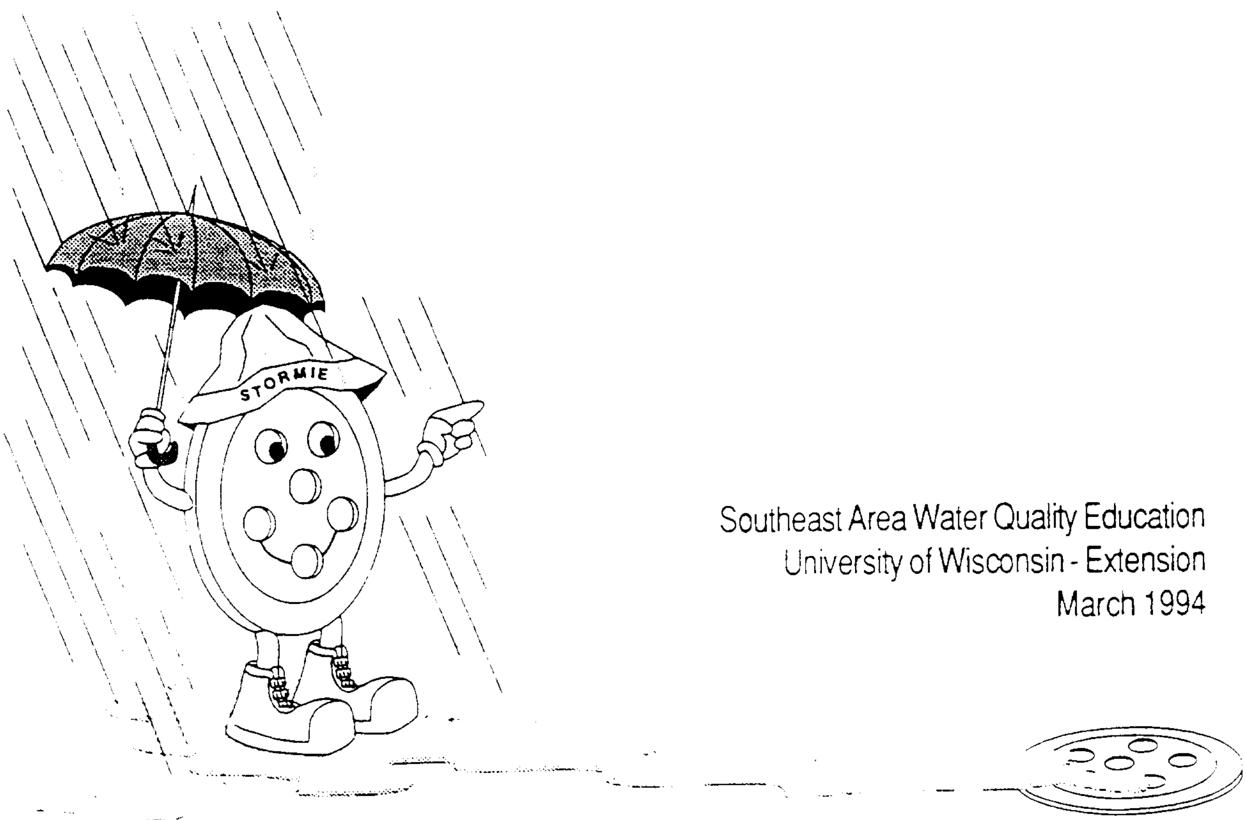
AUDIENCES

Spreading the Word On Storm Water

A Strategy for the Milwaukee Area



Southeast Area Water Quality Education
University of Wisconsin - Extension

March 1994

PROGRAM UNDERSTANDING: Increase understanding of the storm water permit program among affected local governments and industries.

SOLUTIONS ACCEPTANCE: Increase acceptance of and motivation to implement storm water controls and pollution prevention practices among local governments, business and industry, and urban residents.

SKILL DEVELOPMENT: Help local governments, business and industry, and urban residents develop the knowledge and skills needed to implement storm water controls and pollution prevention practices.

IMPACT EVALUATION: Provide information to and solicit feedback from local governments, business and industry, and urban residents about the impact of storm water cleanup efforts.

Target Audiences

Target audiences that must be reached to address these sources of polluted runoff include:

- URBAN RESIDENTS
  - Residents with yards and gardens
  - Vehicle owners
  - Pet owners
  - Schools and youth groups
  - Community groups
- LOCAL GOVERNMENTS
  - Elected officials
  - Staff and consultants
- BUSINESS AND INDUSTRY
  - Automotive businesses
  - Building maintenance
  - Construction
  - Fleet maintenance
  - Landscaping and related businesses
  - Marinas and boat maintenance
  - Mobile cleaning services
  - Outdoor storage and processing
  - Parking lot and grounds maintenance

The Chapter 3 discusses characteristics of each audience and recommends appropriate information and education programs.

FIGURE 5

Ten Keys to a Successful Media Campaign

1. Build on existing themes, mascots and materials—especially the "It All Adds Up" and the "Stormie" cartoon character.

2. Target materials to reach all income, age and cultural groups using appropriate languages, themes, music, media outlets, etc.

3. Use a variety of messages, times and media to reach the critical threshold where people will remember and act on the information they have received.

4. Make the content and tone of messages positive.

5. Appeal to motivations such as clean neighborhoods, health and safety, environmental quality, convenience.

6. Build on what people already know and use sources they consider credible.

7. Use terms that people can easily understand such as "runoff" rather than "nonpoint source pollution."

8. Match the media to the message, keeping in mind that:

    - Print media are most effective for messages that require absorption of details and contemplation by the receiver;

    - Television has the strongest emotional impact, but is the most costly; and

    - Radio's advantages are flexibility and the ability to reach specific target audiences multiple times at a markedly lower cost than television.

9. Use graphics and sound to reinforce messages and make them more memorable.

10. Localize messages, but where appropriate, tie them to national and international events.

1. Internal review during development
   - By author
   - By colleagues
   - By editing, layout, and illustration staff

2. External review during development
   - By staff in other agencies
   - By advisory committee members
   - By potential users

3. User feedback
   - Records of use (numbers distributed, audiences, types of events)
   - Suggestions, complaints, and comments (tracked for revisions or new materials)
   - Requests for further information (through storm water hotline or direct inquiries)

In some cases, a more formal review through mail-back forms, telephone surveys or focus groups will be appropriate.

Evaluating Programs

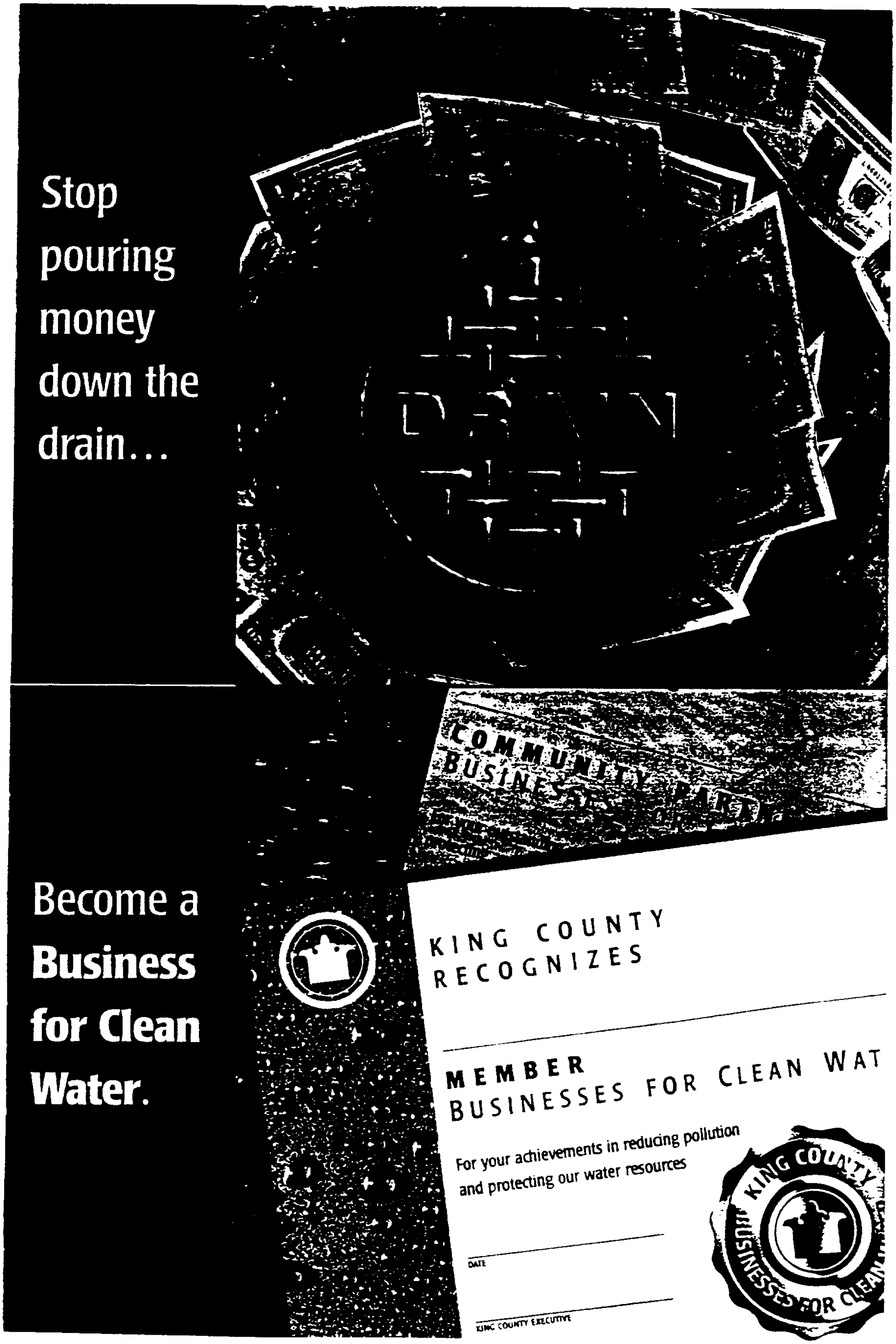
The evaluator's primary responsibility is to gather and interpret information that can help key individuals and groups improve efforts, make enlightened decisions, and provide credible information for public consumption.

Worthen and Sanders 1989

Educational programs such as workshops, staff training and school curricula require even more extensive evaluation. Evaluation typically begins with a planning or steering committee that identifies educational outcomes, oversees program development, designs evaluation tools, analyzes results and makes recommendations for future programs. Commonly used tools include:

1. Records of participation
2. Pre/post tests
3. Evaluation forms
4. Informal evaluation (discussion, show of hands, comments)
5. Records of requests for further information or additional programs
6. Telephone surveys or interviews of participants
7. Case studies of participants
8. Reviews by planning or steering committees
9. Reviews by external agencies

Evaluations methods must be selected for each program based on the type of information needed as well as available time and resources. Each


Stop pouring money down the drain...
Become a Business for Clean Water.
KING COUNTY
RECOGNIZES
MEMBER
BUSINESSES FOR CLEAN WAT
For your achievements in reducing pollution and protecting our water resources
DATE
KING COUNTY EXECUTIVE

R0026282

King County Promotes Your Business for Your Pollution Prevention Efforts

Polluting is like pouring money down the drain—it costs less to prevent it than to clean it up. It's also against the law. When it rains, water carries pollutants into storm drains that lead to lakes and streams. To prevent pollution, sweep your parking lots, cover dumpsters and stored materials, and wash cars in contained areas. **Get recognized for protecting water quality—Become a Business for Clean Water today.**

"I used to think rainwater went to the treatment plant—but only water in toilets and sinks goes to the sanitary sewer for treatment. Most outdoor drains go directly to streams and lakes."

—Yvonne Johnson, Property Manager
Yates, Wood & MacDonald, Inc.

How to get started:

Any business in **unincorporated King County** is eligible to become a member of Businesses for Clean Water by following these steps:

- Call 296-1900 to schedule a **free consultation** and learn what your business needs to do to protect water quality.
- Show us that you have implemented required practices to prevent pollutants from entering storm drains, lakes, wetlands and streams and become a Member.
- Be more than a Member—become a Community Partner—by educating other businesses and the community.

Become a Business for Clean Water and Receive:

- Free publicity in newsletters, newspapers, directories and more.
- A certificate and other materials that show your customers, community and employees that your business works to protect our environment.
- Best of all, you'll have a well-maintained business, reducing costs, time and liability.

"By becoming familiar with pollution prevention measures and properly maintaining your site you'll save money in the long run."

—Denise Hidano, Boeing Computer Services

King County
Surface Water Managment Division
700 Fifth Avenue, Suite 2200
Seattle, Washington 98104

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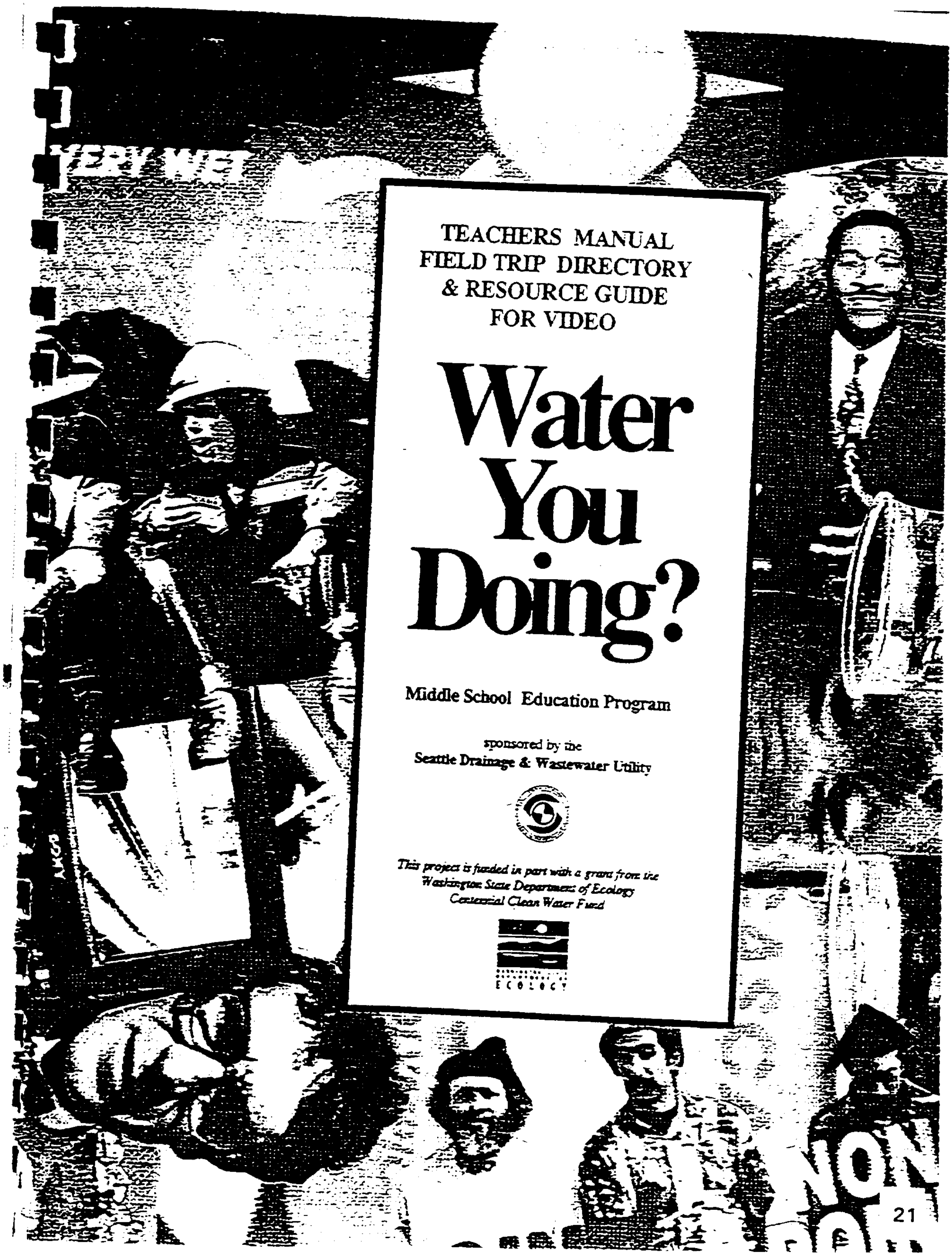


TEACHERS MANUAL
FIELD TRIP DIRECTORY
& RESOURCE GUIDE
FOR VIDEO

Water You Doing?

Middle School Education Program

sponsored by the
Seattle Drainage & Wastewater Utility

This project is funded in part with a grant from the Washington State Department of Ecology Centennial Clean Water Fund

Seattle
Engineering Department

Gary Zarker, Director
Norman B. Rice, Mayor

November, 1992

Dear Educator,

Welcome to the Seattle Drainage and Wastewater Utility Middle School Education Program!

Mention Seattle to someone and immediately thoughts of water, water resources, and spectacular scenery come to mind. Puget Sound and all the surrounding lakes, rivers, and streams offer unparalleled recreation opportunities, commercial and sport fishing, one of the world's leading seaports, high quality drinking water, and even electricity. Seattle's residents value clean water and are willing to pay the cost of protecting and preserving this resource.

The Drainage and Wastewater Utility (DWU), a division within the Seattle Engineering Department, is the agency primarily charged with the responsibility for preventing water pollution in Seattle. To that end, DWU places a high value on environmental education of all age levels in an effort to promote non-polluting behavior. DWU is developing educational tools, such as this video and teachers manual, to assist Seattle and other school teachers with their environmental education programs. These tools will help school age children build a sense of respect for our natural water resources and provide them with the opportunity to develop clean water ethics within their school community, their family, and their neighborhood.

Sincerely,

Richard Gustav	Anthony Matlock	Carlton Stinson
Senior Planner	Education Specialist	Education Specialist

Seattle Engineering Department, Room 400, Seattle Municipal Building, 600 Fourth Avenue, Seattle, Washington 98104-1879 (206) 684-5000 TDD (206) 233

INTRODUCTION

This manual is part of an overall water quality education program designed by Seattle Drainage & Wastewater Utility for the students and teachers of Seattle middle schools. The material in this manual reinforces and enriches the concepts presented in the video entitled "Water You Doing".

Together, the video and this manual, along with the accompanying Field Trip Guide, can be used to instruct students of Seattle about some of the issues involved in managing and maintaining water quality within our city.

Because of the uniqueness of individual schools and classrooms, the materials were created to allow teachers maximum flexibility. The information can be taught in a variety of settings with a time commitment ranging from just one class period to an engrossing five weeks or more of in-depth studies.

THE VIDEO

The video is divided into five segments, each segment running an average of six minutes. One segment, followed by an activity and discussion, is structured for a 40-minute class period. The ideal or optimum approach would include a week of studying and interacting with the video and the manual's suggested activities.

THE MANUAL

The manual uses a matrix format. For each video segment, the matrix includes a selection of video foci, learning objectives, bridging questions and suggested activities. This menu-style format was adopted so the selection of approaches could be as effective as possible for various learning environments. At the very minimum, the topic of drainage and wastewater can be taught within one class period. The manual, however, includes other materials for the instructor who desires to extend the topic into a full five-week unit.

THE FIELD TRIPS

A field trip is a unique opportunity for students and teachers to visit and experience some of the lessons and activities offered in the various segments of the video and manual. The Select Trips are fully funded including bus transportation, admission fees and teacher substitutes. Special

(over)

arrangements will be made for any teacher who is interested in the Optional Trips. Further information can be found in the *Field Trip Directory*.

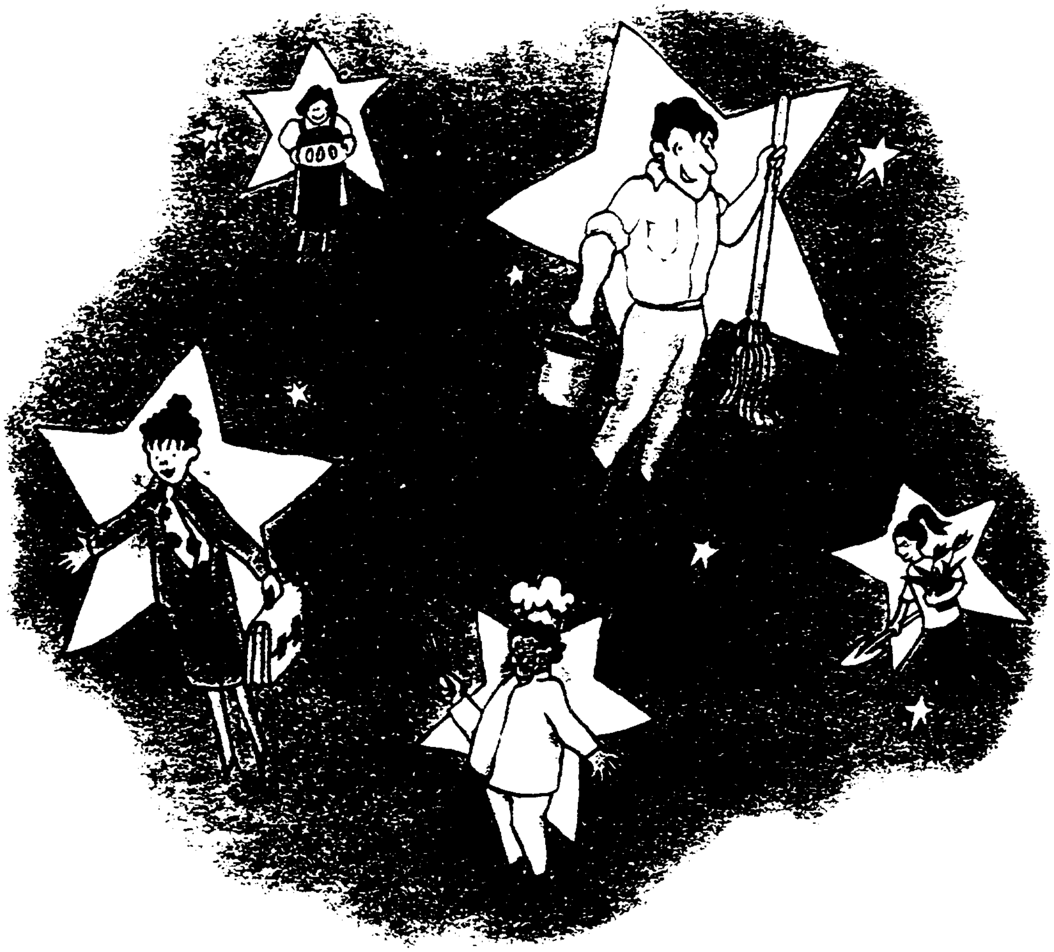
FOR MORE INFORMATION

We are happy to assist you with any questions about procedures or additional information and materials. Please call:

Rich Gustav
Senior Planner
Drainage & Wastewater Utility
660 Dexter Horton Building
Seattle, WA 98104
(206) 684-7591

This educational program is made possible by the Seattle Drainage and Wastewater Utility, a division of the Seattle Engineering Department, and is funded, in part, with a grant from Washington State Department of Ecology Centennial Clean Water Fund.

STRATEGIES



Promoting Stewardship of Puget Sound

More PIE Success Stories

PUGET SOUND WATER QUALITY AUTHORITY

Promoting Stewardship of Puget Sound

More PIE Success Stories

April 1996

Puget Sound Water Quality Authority
P. O. Box 40900
Olympia, WA 98504-0900
(360) 407-7300 or 1-800-54-SOUND

Produced through funding from the Public Involvement and Education Project, financed by proceeds from the Washington State Centennial Clean Water Fund and administered by the Puget Sound Water Quality Authority. This publication may be reproduced.

PUGET SOUND WATER QUALITY AUTHORITY

Introduction

In the end, we will conserve only what we love, and we will love only what we understand
— Baba Dioum, Senegalese conservationist

In 1987 the Puget Sound Water Quality Authority created one of the most powerful tools available for protecting and improving the region's water quality — the PIE (Public Involvement and Education) Fund. The success of this innovative approach lies in the fact that it provides funding to community-based projects that build stewardship for Puget Sound. In the last nine years, the Authority has provided more than $4 million for 230 projects. These projects have spread the message of clean water to at least two million people.

Local Problems, Local Solutions

At the heart of the PIE Fund is the belief that community-based organizations, businesses, local and tribal governments, and schools can involve and educate people about water quality in ways that government, by itself, cannot. Local groups best understand the needs within their own communities, and are best prepared to manage local resources. Through PIE, the Authority has provided direction, funds and technical assistance to enable project sponsors to act on local needs.

In 1987 this philosophy appeared risky and the PIE Fund was very much a pilot program. Today, after hundreds of successful projects have netted tangible improvements in Puget Sound and increased public understanding of water quality, the program has proven its merits as a valuable and responsible method for implementing water quality protection called for in the *Puget Sound Water Quality Management Plan*. The PIE Fund has been used by other states as a model in developing their own public involvement and education programs.

As the PIE program has grown and evolved, so have the PIE projects. Partnerships and alliances among groups with different missions and philosophies is becoming commonplace. Sponsorship from businesses and their related associations has grown. Projects aimed at involving a variety of ethnic groups, particularly non-English speaking people, has grown and, as a result, government agencies are learning how to bridge language and cultural barriers (though much work in this area remains).

Criteria for a Successful PIE Project

- Move beyond "us versus them" attitudes and emphasize that good water quality is in everyone's best interest.
- Emphasize interesting, innovative activities that involve people, put them in charge of decisions and lead to local action.
- Be well-designed and clearly articulate effective methods for reaching identified target audiences.
- Support cleanup and protection of Puget Sound waters.
- Be carried out by groups which have demonstrated their abilities to implement the project they propose.
- Clearly justify expenditures.
- Be guided by an advisory group, which includes a cross-section of affected people (for example, a mixture of business people, local government staff, citizen group representatives and technical experts) as needed for the particular projects.

Before qualifying for PIE funding, projects undergo thorough evaluation by Authority staff and a 12-member Education and Public Involvement Advisory Committee. The committee — which includes educators, business people, farmers, interested citizens, representatives from local and tribal governments, and at least one former PIE contractor — and staff review projects. The process is very competitive — only one of five proposals typically receives funding.

Raspberry Farm Improvement Clubs

This project established Raspberry Farm Improvement Clubs to enable raspberry farmers to experiment with techniques to reduce pesticide use on their farms and share their findings with other farmers.

Project Design

Project staff encouraged farmers to establish Raspberry Farm Improvement Clubs. Through the clubs, farmers developed and performed experiments designed to reduce pesticide use. The farmers received technical assistance from researchers to help develop research proposals. Each club designed an experiment to find a non-chemical solution to a pest problem and carried out the experiments on their own farms.

Results

- Three Raspberry Farm Improvement Clubs developed different experiments to meet their needs and reduce pesticide use. Farmers demonstrated their successes to other farmers through farm visits. The information from the experiments was shared at meetings and workshops and has advanced the knowledge base for alternatives to pesticides.
- Organic raspberry farmers who have been looking for information and help with organic growing techniques now have other farmers to talk to and new techniques to use.
- A strong coalition of farmers, environmentalists, private consultants and researchers formed to broaden support for integrated pest management and to disseminate information on production practices that reduce pesticide use on farms.
- An entirely new way of thinking about pests and pest management was introduced within the farming community and farmers themselves became the ones to find the best techniques and spread the word.

Notes

Peer learning is usually the best way for knowledge to spread. In this project, the farmers worked together to solve problems associated with pesticide use. As members of the Washington Red Raspberry Commission and other farming groups, the farmers became spokespersons for new methods developed in the project.

Perspective

"Six months ago you couldn't get someone to talk about alternatives to pesticides. Now there is a lot of interest." —*Jerry Dobbins, participating raspberry farmer*

Sponsor: Northwest Coalition for Alternatives to Pesticides, P.O. Box 1393, Eugene, OR 97403 (503) 344-5044

Coordinator: Gwendolyn Bane

PIE Funding: $9,015

Additional Resources: $1,200

Timeline: June 1994 - May 1995

Target Audience: Commercial and non-commercial red raspberry growers, researchers and industry representatives in Washington

DOWNSTREAM NEWS

King County Surface Water Management
Everyone lives downstream

VOLUME SIX · NUMBER TWO · SPRING 1996

Downstream News is dedicated to educating and inspiring people *like you* to protect and enhance King County's water resources.

County Executive awards 1996 Community Stewardship Grants with help from Westside School students

At a March ceremony hosted by Westside **School** in White Center, **County Executive Gary Locke** and Westside students presented grant awards to representatives from 12 schools and community groups. Funded both by SWM's Community Stewardship program and by Waterways 2000, the 1996 grantees received a total of $45,000 for a variety of stewardship and education projects in the coming year to protect and enhance King County's water resources.

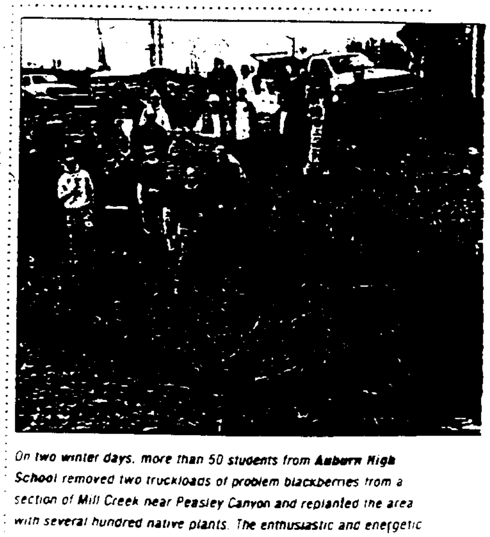
County Executive Gary Locke presents a grant award to teacher Ted Holmes and Westside School students.

With their grant awards, the groups plan to:

- Remove invasive weeds and plant natives along Bear Creek near Woodinville.
- Create and install an interpretive sign near Seola Creek.
- Continue community cleanups of the creek and create a web page.
- Protect, clean up and provide educational opportunities associated with the Shadow Lake bog east of Kent.
- Monitor water quality and educate residents about non-point pollution in the Lake Sawyer watershed near Black Diamond.
- Distribute a Duwamish watershed bike tour pamphlet and develop new educational watershed bike tours.
- Coordinate monitoring, teacher training and a watershed atlas for Thornton Creek.
- Create and distribute a student-made brochure to neighbors to encourage community stewardship in the Cedar River Watershed.
- Plant native riparian species and create an interpretive sign about invasive plants as part of a larger meadow restoration on Cougar Mountain.
- Recruit and train urban youth to do restoration projects in the Green and Duwamish Watersheds.
- Create a video on wetland birds as a tool to teach wetland monitoring.
- Build and maintain a native plant nursery to supply public restoration projects.
- Create an interpretive sign at a park beside the Cedar River, educate park neighbors and monitor the river.

The 1996 Community Stewardship Grant recipients are: **Westside School, Bear Creek Elementary School**, the **City of Black Diamond, Tahoma School District, Maple Valley Rotary, Rainier Audubon Society's Wetlands Group,** Lakeside School, Seattle Aubudon's WETNET, **Cascade Bicycle Club, Issaquah Alps Trails Club, Renton Fish and Game Club**, and the

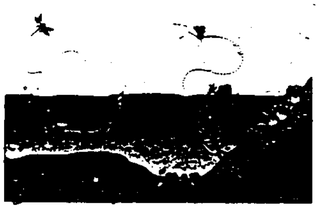
(continued on page 3)



*On two winter days, more than 50 students from **Auburn High School** removed two truckloads of problem blackberries from a section of **Mill Creek near Peasley Canyon** and replanted the area with several hundred native plants. The enthusiastic and energetic group came from the science classes of teachers **Stu Dick** and **Bob Rollins**.*

First, take a medium-sized stream....

Want to put on a community stewardship event but not sure where to start? Turn to SWM's Community Stewardship "How-to Kit", a collection of checklists, handouts and other resources groups can use to put on their own events. Compiled in an easy-to-use binder, the kit was put together by SWM staff as a result of their partnership with **Water Tenders**, a Bear Creek community group. If you're interested in a copy, call **Pat Johnson at 296-8029.**



Stewardship Grants

(continued from page 1)

Student Conservation Association.

As the 1996 grantees begin their Community Stewardship grant projects, last year's grantees are just completing their 1995 projects. More than 2,700 citizens actively participated in the protection of their waterways through last year's grants. They planted thousands of trees, installed more than 3,000 feet of fencing and built several hundred feet of trails. School students around the County learned about frogs and aquatic insects, grew native plants for a variety of restoration projects, and monitored and cleaned-up streams and wetlands near their schools.

With this year's grant awards, the Community Stewardship and Waterways 2000 grant programs have funded 88 projects since 1988 for a total investment of almost $200,000 in protecting the County's water resources. Stay tuned for more details on the 1996 Community Stewardship Grant projects. If you'd like to be notified when next year's grant applications are available, please call Pat Johnson at 296-8029.

Teachers: check out these environmental education resources

There's a wealth of classes and curriculum materials out there this summer to help you teach your students about water resources. Read on for details!

Classes, classes, classes!

- Sign up for one or all of the summer workshops for educators sponsored by the **Thornton Creek Alliance.** From June 22 to 27, learn about GIS, urban watersheds, monitoring and how to use data in the classroom. To find out if space is available, e-mail **Peter Hayes** at **peter_hayes@morrislakesidesea.wa.us** or call him at **440-2754.**
- **The North Cascades Institute** offers a variety of great workshops: check out *Watershed Week for Educators* (July 8-12 in North Cascades National Park), *Where the Forest Meets the Stream* (July 19-21 at Rockport State Park) or *Aquatic Insects: Riparian Habitats and Stream Ecology* (August 10-11 at Baker Lake Basin). For prices and availability, call **(360) 856-1934** or e-mail **nci@ncascades.org**. Or browse their catalogue at **http://www.ncascades.org/nci/**

- And it's not too early to mark your calendar for **TREE3!** The third annual TREE (Teaching Resources for Environmental Education) Fair is scheduled for **October 11** at **Eckstein Middle School** in Seattle. From workshops and exhibits, you'll get tips, lesson ideas and materials on a variety of topics, including watersheds, recycling, energy conservation and much more. For a flyer or more information on attending or exhibiting, call **Polly Freeman** at **296-8359** or e-mail her at **polly.freeman@metrokc.gov**
- Teach kids about rivers and forests! The **Nisqually River Education Project** has put together a guide for educators called *Where the Rivers Begin*, about the rivers and adjacent old-growth forests in **Mount Rainier National Park.** The park offers one-day teacher workshops on using the guide, which is now available in hard copy and on CD-ROM. Call the Park's Education Office at **(360) 569-2211, X3313** for more information.

BUSINESS ASSOCIATIONS CAN GET UP TO $7,500 TO KEEP WATER CLEAN

Business associations and Chambers of Commerce can apply for grants to fund projects in which businesses work together to improve and protect King County's water resources. Possible projects could include promoting pollution prevention practices, producing educational materials or educating and training employees. Target businesses must be located in SWM's service area (the western third of unincorporated King County). Applications are available now and proposals are due on July 1. For more information, call Sandra Kilroy at 296-8047.

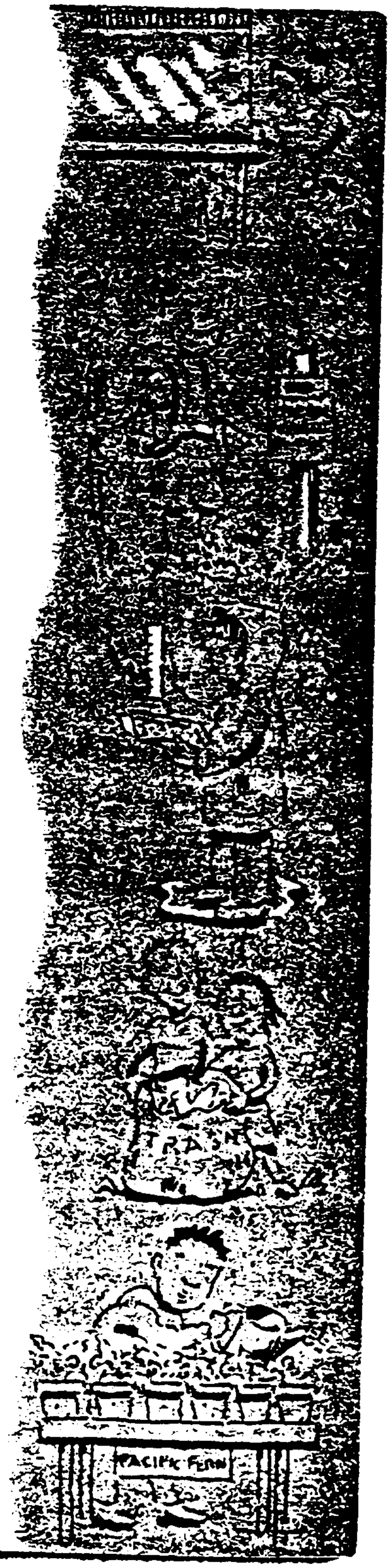
Have you seen this on TV?

ADS ON TELEVISION are just one of the ways local cities and government agencies are encouraging Lake Sammamish area residents to keep phosphorus out of the lake this spring and summer. Interpretive signs in Lake Sammamish State Park, doorhangers distributed around the watershed and low-phosphorus gardening displays at area nurseries are spreading the word to limit phosphorus inputs to the lake.

Why no "phos" for us? Excess phosphorus that reaches the lake stimulates dense growths of algae, turning the lake a cloudy green, causing ugly surface scums and ultimately harming recreational use, fish habitat and water quality. To keep phosphorus out of the lake, apply fertilizer to your yard sparingly, take your car to a commercial carwash, scoop pet waste and make sure your septic tank is in good repair.

Interested in helping get the low-phosphorus message out to your neighbors? Call Polly Freeman at 296-8359 to distribute doorhangers around Lake Sammamish or to learn more about the campaign to control phosphorus pollution.

1996 Community Stewardship Network Directory



King County
Department of
Natural Resources

King County
Surface Water
Management
Everyone lives downstream

What you hold in your hands is a comprehensive directory of community and non-profit groups, government agencies and businesses involved in restoring and protecting the watersheds of King and other Puget Sound counties. This book will help you make new friends, seek assistance from government and business and get connected with efforts to keep our local waters clean.

How to use this directory:

The directory is organized by watershed, city, and group (community/non-profit groups, schools, government agencies, businesses, and independent services). There are two ways to use the directory:

1. Look up the city closest to you. Learn your watershed and find the groups, schools, agencies, businesses and independents that are doing projects in your area. Each listing contains information on what is available and who to contact.

2. Use the group activity charts. At the end of the city and watershed listings, you will find charts that list cities and groups on one side and topics (like wetlands or revegetation) on the other. A dot at the intersection of the row and column indicates what topics are covered by what groups. See pages 58-75

Now that you have this directory, use it to protect our watersheds. Share it with your friends.

Lower, Middle Green River Basins

Auburn, Tukwila

ARHS Science and Natural Resource Departments

501 Oravetz Rd.
Auburn, WA 98092

Mrs. Shaw
Mrs. Kurka 804-5154

Educates students and the community.

Auburn, City of Storm Drainage Utility

25 W. Main
Auburn, WA 98001

Chris Thorn 931-3010

Storm and surface water management

Auburn High School

800 Fourth St. NE
Auburn, WA 98002

Sandra Burroughs 931-4884

Metro grant recipient, 1991. Monitored water quality through chemistry and aquatic insect studies.

Creature Comforts Kennels

36215 55th Ave. S.
Auburn, WA 98001

Larry Willoughby
Denise Willoughby 833-2200

Member, King County Businesses for Clean Water Program. Protects water quality by implementing pollution prevention practices described in King County's Stormwater Pollution Control Manual.

East Hill Environmental Citizens Alliance

10926 SE 274th St.
Kent, WA 98031

Charlie Kiefer 854-5889

Community watchdog group in the vicinity of Olson and Mill Creeks.

Friends of the Green (River)

10510 11th Ave. NE
Seattle, WA 98125

Pat Sumption 525-1708

Primarily involved with protection of the Green River and water conservation issues.

Green/Duwamish Watershed Alliance

1326 Fifth Ave., Suite 450
Seattle, WA 98101

Mike Murphy 382-7007

An alliance of community groups, schools, business and government which promotes stewardship, encourages citizen participation in watershed programs and assures efficient use of public and private resources.

Community Group · Schools · Government · Business

Group/Activity Chart

GROUP NAME	Other	Workshops	Wetlands	Watersheds	Volunteer Projects	Streamwalks	Storm Drain Stenciling	Speakers Available	Salmon	Revegetation	Noxious Weeds	Newsletter	Native Plants	Monitoring	Lakes	Grants Available	Education Material	Displays/Exhibits	NOTES
Auburn, Tukwila																			
ARHS Science and Natural Resource Departments					●								●				●		
Auburn, City of - Storm Drainage Utility								●						●			●		
Auburn High School														●					
Creature Comforts Kennels	●																		Business best management practices
Friends of the Green (River)		●		●	●	●		●		●							●	●	
King County Surface Water Management, Green River Basin Steward		●	●	●	●	●		●	●	●	●		●	●	●		●	●	
Lake Killarney Improvement Association		●	●								●	●		●	●				
Lake View Elementary														●					
Olson Creek Stewardship Committee				●					●					●					
Rainier Audubon Society			●	●	●							●		●			●	●	
Star Lake Improvement Club					●		●							●	●		●		
Thorndyke Elementary Fourth Grade									●								●		
Tukwila, City of					●		●	●						●			●	●	
Washington Environmental Training Center, Green River Community College		●						●											
Bellevue, Factoria, Newport Hills																			
Ace Carnozian Carpet Cleaning	●																		Business best management practices
Bellevue, City of - Resource Management Division, Parks and Recreation Dept.			●		●			●		●	●							●	
Bellevue, City of - Stream Team Program		●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	
Bellevue Parks and Community Services			●		●	●												●	
David Evans and Associates		●	●	●				●		●				●			●		
East Lake Washington Audubon Society		●	●		●	●		●				●		●			●	●	
Hedges and Roth Engineering								●											
Mercer Slough Environmental Education Center		●	●														●		
Newport Hills Community Club												●							
Phantom Lake Homeowners Association						●				●	●			●	●				Offers information on a variety of topics
Puget Sound Native Plants			●										●						
R.E.I., Bellevue					●														
YMCA Earth-Corps														●					
Burien, Des Moines, White Center																			
American Indian Heritage School		●				●	●	●	●	●			●	●			●	●	
Burien, City of	●		●	●	●		●												Surface water issues
Cascade Middle School										●				●	●				
Des Moines, City of		●			●		●					●		●					
Des Moines Creek Basin Committee				●	●														
Kiwanis of Highline														●					
Miller Creek Management Coalition	●			●	●														
Sunnydale Elementary School																	●		

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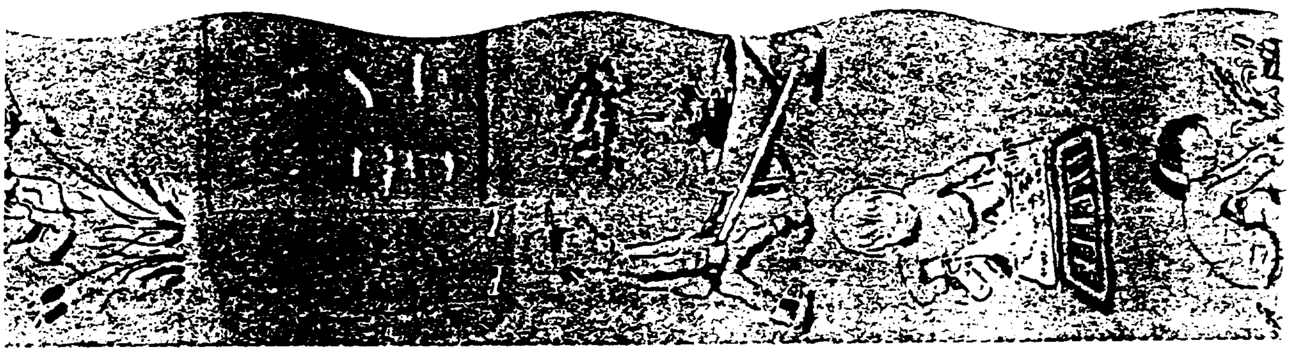
King County Department of Natural Resources

King County Surface Water Management



❑ ***Please list us in the 1997 Community Stewardship Network Directory.***

Group Name ____________________
Address ____________________
City __________ Zip __________
Contact person ____________________
Phone ____________________

❑ Community group/Non-profit ❑ School
❑ Government Agency ❑ Business

Note: To be listed, businesses must offer a relevant product or service at no cost

Check the information you have to share: ❑ Displays/Exhibits ❑ Educational Materials ❑ Grants Available ❑ Lakes ❑ Monitoring ❑ Native Plant Propagation ❑ Newsletter ❑ Noxious Weeds ❑ Revegetation ❑ Salmon ❑ Streamwalks ❑ Speakers Available ❑ Storm Drain Stenciling ❑ Volunteer Projects ❑ Watersheds ❑ Wetlands ❑ Workshops ❑ Other __________

Main emphasis ____________________

❑ I know another group that should be listed: Name: ____________________

Questions? Call Bob Spencer at 296-1951.

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R0026328

Controlling Oil Pollution in Surface Water

Home | Glossary | References

PROBLEM
Science
Uncontrolled pollution
Economic Damages
SOLUTIONS
Technical Options
Policy Options
Current Regulations
Community Activities
Analysis

This website provides an overview and analysis of the problem of storm water-related oil pollution in the US and how it is being addressed. Referring to a wide array of related sites, we describe and discuss the current US federal, state and municipal approaches to safeguarding cleaner and safer water resources in the United States.

R0026329

V625 Environmental Economics and Policy, Spring '99

Dr. Kenneth Richards

Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

School of Public and Environmental Affairs, Indiana University *Bloomington, Indiana*

R0026330

PROBLEM

Home | Glossary | References

Why do we care about non-point source oil pollution?

In 1969, the Cuyahoga River in Ohio caught on fire because it became flammable after years of uncontrolled pollution. The horrifying event served as a wake-up call to the American public to address the deteriorating condition of many US rivers, lakes and estuaries. Three years later the Clean Water Act was passed with the objective to make all waterways of the US safe for fishing and swimming by the year 1983. Although this goal still has not been reached, water pollution control has come along way in the last 25 years.

In 1972, two-thirds of our water bodies were unfit for swimming or fishing. Thanks to extensive clean-up ef two-thirds of the water bodies in the country are considered clean and safe, but the remaining one-third of U waters are still considered unsafe. 99% of the five Great Lakes and more than 27,000 Midwest inland lakes advisories to the public that some fish are not safe to eat. While direct discharge from factories has been nea eliminated, our water continues to be poisoned by sources more difficult to handle: non-point sources of pol (Sierra Club Oct 1997).

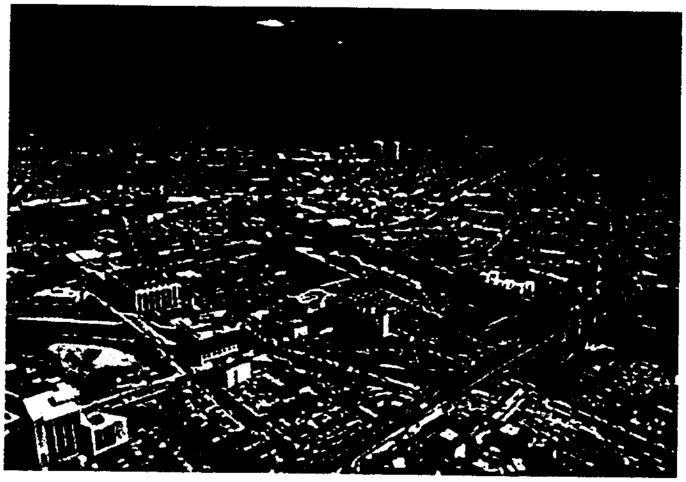
The problem

Polluted stormwater runoff creates surface water pollution. Surface runoff becomes polluted as it flows ove rooftops, paved areas, bare soil, and through sloped lawns. As it moves over these surfaces it collects soil, p waste, salt, pesticides, fertilizer, oil, grease, leaves, litter, and other pollutants to carry with it on its journey nearest body of surface water.

Stormwater may also collect in storm drains, surface ditches, and sewers, which carry these the substances u they reach a river, lake or estuary within its watershed. Contrary to popular belief, many storm sewers do no carry storm water to sewage plants for treatment.

Oil products in surface water are particularly troublesome. There are two main reasons for this.

- Chemicals in oil are so toxic that even small amounts are very harmful to living things.
- Oil pollution comes from non-point sources that are difficult to control because their origin is not associated with particular geographic locations.



Examples of non-point oil polluters of water inc cars, trucks, boats and machinery for agricultura forestry and construction purposes. Yet one of th greatest contributers to petroleum pollution is individual owners of motor vehicles. As we shal in the following section, illicit discharge of motc is a major casue of oil pollution of surface water

On the left: Brooklyn, NY

Although most such sources *individually* pollute only in small amounts, *collectively* they do serious har the natural environment.

Cleanup of oil-contaminated water can be extremely difficult and expensive. Efforts to control oil-polluted s water runoff is therefore focusing on preventive measures – to make sure that spills or leaks do not occur in first place - rather than trying to clean up polluted waters.

Nonpoint Source Pollution Control Program
U.S. Environmental Protection Agency — Office of Water

For more information on non-point source polluti see EPA's Office of Water's Nonpoint Source Pol Program:http://www.epa.gov/OWOW/NPS/roads

TOP OF PAGE

Home | Glossary | References

V625 Environmental Economics and Policy, Spring '99, Dr. Kenneth Richards ,

Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

R0026332

Env. chem

Home | Up | Glossary | References

Environmental Chemistry of Waste Oil

When waste oil is released into the environment, its chemical and physical characteristics change through a process called weathering. Essentially, weathering occurs as a response to exposure to ambient environmental conditions. Weathering tends to remove the volatile, or aromatic constituents and those that are easily metabolized by microorganisms (Hall and Coon 1988).

The major constituents of concern in waste oil are benzene, toluene, styrene, benzo(a)athracene, napthalene, and benzo(a)pyrene (Mueller Asso. 1989). Each of these constituents is subject to the weathering process, and the exact weathering products of waste oil depend on ambient environmental conditions. For instance, in an aquatic environment, the breakdown products of benzene include butylphenylether, benzophenone, toluene, nitrobenzine, and aniline (Marchini et al. 1992).

After oil enters an aquatic environment, its constituents remain suspended in the water column for a few days. These constituents then migrate into sediments, where they can remain for years (Brown 1980).

In general, there are **seven processes** that can act on pollutants in aquatic environments (Barber et al. 1995)

1. Stick to sediments, where they concentrate (sorption and deposition),
2. Come loose from sediments and reenter the water column (desorption and diffusion),
3. Biological transformation into intermediate compounds or completely biodegraded.
4. Aromatic compounds may enter the atmosphere (volitalization),
5. Accumulate by way of bioaccumulation in animals,
6. May be broken down by sunlight (photolysis), or
7. May be broken down by interactions with water (hydrolysis).

Any or all of these processes can act on constituents of waste oil in surface water.

For a graphic illustration of the fate of oil products in the environment, click HERE.

TOP OF PAGE

Home | Up | Glossary | References

V625 Environmental Economics and Policy, Spring '99, Dr. Kenneth Richards ,

Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

R0026333

Toxicology

Home | Up | Glossary | References

Biological Effects of Uncontrolled Waste Oil Pollution

HEALTH EFFECTS: WILDLIFE, HUMANS and BIOACCUMULATION

Toxicological studies of the effects of petroleum products on living organisms have focused mainly on the effects of spilled crude on marine organisms and on the effects of processed petroleum products on humans. Probably because waste oil varies depending on how it was used, relatively few studies that were available t us looked specifically at the effects of waste oil in surface waters on human and wildlife health. Nonetheless few studies have been done, and we will extrapolate from studies in marine environments to roughly assess effects in surface waters.

Health effects in wildlife

Brown (1980) performed a variety of experimental investigations into the effects of crude oil from various sources on aquatic plants and animals in southern Louisiana. He found that a measured amount of oil introduced into an experimental brackish marsh ecosystem reduced plant productivity by 88% and, because plants were not growing as quickly, that the oil had long-term effects on the addition of usable organic matt the ecosystem. Populations of zooplankton, which are microscopic animals that live water, declined immediately after the introduction of an oil load into Brown's study area, but these organisms recovered the numbers within two weeks. Crustaceans and fish suffered from behavioral changes and pathological effects. Both types of animals initially swim to the surface and show motor disturbances, both of which make them l able to avoid predators. Long-term, both types of animals suffered from lethal or sublethal skin diseases. Th diseases are thought to occur when oil constituents selectively kill beneficial bacteria that live on exposed tissue. This selective killing of beneficial organisms allows pathological organisms to proliferate, causing disease and death.

The effects of crude oil on birds has been extensively studied in marine environments. Ingested crude oil ca slower growth, damages internal organs, and decreases reproductive success (studies in Hall and Coon 1988

Other workers have found that benzene and its derivatives cause lethal and sublethal effects in freshwater minnows (Marchini et al. 1992).

Health effects in humans and laboratory animals

Summarized in chart below:

R0026334

Compound	Exposure pathway	Physiological targets	Acute effects	Chronic effects	Source
Benzene	Inhalation, skin contact	CNS, metabolized by liver	Severity of CNS depression ranges from confusion up to coma. Destroys bone marrow, may cause chromosomal abnormalities. Known carcinogen, aute myeloblastic leukemia is most common. Lethal to freshwater minnows at moderately high doses.	Accumulates in fat	Hume and Ho 1994, Hall and Coon 1988
Ethyl benzene	Inhalation, skin contact	CNS	Severity of CNS depression ranges from confusion up to coma	Not known	Hume and Ho 19
Toluene	Inhalation, skin contact	CNS	Severity of CNS depression ranges from confusion up to coma, may cause birth defects.	Not known	Hume and Ho 19
Xylene	Inhalation, skin contact	Kidney, body fat, nerves, lungs, brain, muscle, spleen.	(1) Severity of CNS depression ranges from confusion to coma-humans (2) Changes in brain chemistry	(1) 5% of inhaled product is stored in body fat.	(1) Hume and Ho 1994 (2) Studies in Burbacher 1993

Bioaccumulation

Bioaccumulation occurs when environmental contaminants are stored in biological tissues and transferred to other organisms through the food web. When this animal is eaten by another, its load of contaminant is transferred to the predator. Each animal can also transfer some of this contaminant to its offspring. Thus, ev if ambient concentrations of a contaminant are low, tissue concentrations in some animals in the ecosystem be quite high.

This process of bioaccumulation can have devastating effects on ecosystems—DDT was a bioaccumulating compound that caused almost total reproductive failure in birds of prey in the 1960's and 1970's. The bioaccumulative potential of petroleum products is reduced by two factors. First, the most abundant constituents are straight-chain hydrocarbons, which are readily metabolized and are not known to be highly toxic (Hume and Ho 1994). Second, the toxic aromatics in oil (benzene, toluene, xylene, etc) are light and volatilize quickly enough that they are unlikely to be ingested in water.

The waste oil constituents of most concern are those that are picked up during lubrication, or solvents that a mixed in during pre-disposal storage.

TOP OF PAGE

Home | Up | Glossary | References

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Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

R0026335

Uncontrolled pollution

Home | Glossary | References

Major Contributors

SOURCES OF POLLUTION | SURFACE RUNOFF POLLUTANT | MICHIGAN STUDY | AMOUNT C

Petroleum pollution of water is often associated with oil spills from big ocean liners like the now infamous Exxon Valdez. A recent report from the National Research Council reveals the truth about the most import sources of oil-pollution (Sierra Magazine 1999). It is clear from the diagram that illicit discharge and urban runoff are the major factors to be considered for control of hydrocarbons (Field 1997. Storm and Combined Sewer Overflow). The graph below illustrates the annual ammount of oil released into the environment worldwide in comparison with the Exxon Valdez.

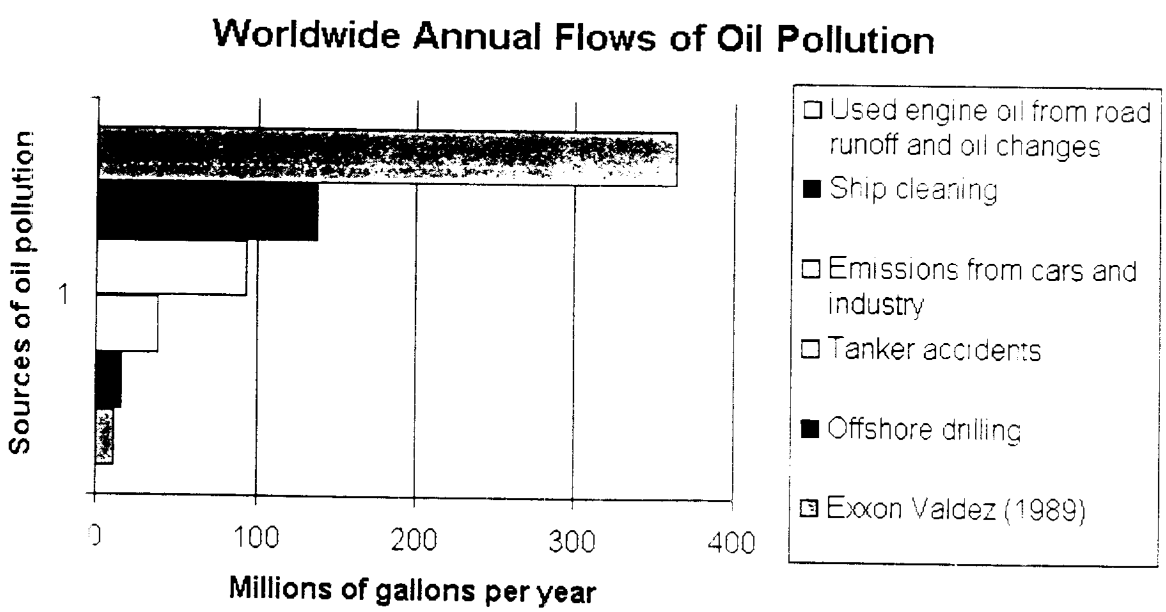


Table 1. Source: National Research Council 1999 (Sierra Magazine March/April 1999, p. 17)

The oil pollution problem in surface runoff

Ongoing studies by EPA have shown that polluted runoff is a major factor in the degradation of water resou in the US. Storm water runoff in particular is considered by the EPA to be the *biggest* current threat to heal national water resources.

In EPA's "National Water Quality Inventory" 1994 report to Congress, the EPA indicates that storm water discharges from a variety of sources, including separate storm sewers, construction, waste disposal, and resource extraction activities, are "major causes of water quality impairment. Roughly 46% of the identified cases of water quality impairment in surveyed estuaries are attributable to storm sewer runoff (EPA 1998. NPDES rule proposal, p. 2).

How does oil get into stormwater runoff?

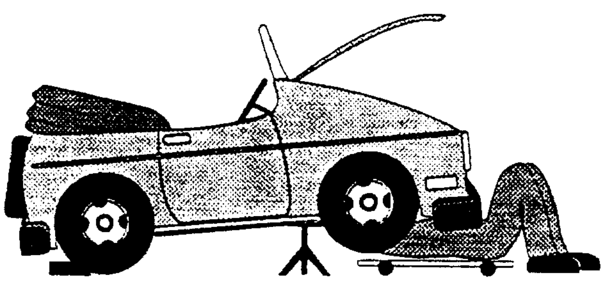
Leaks and dumping: In urban or construction contexts, oil and grease are may leak onto road surfaces from car and truck engines, may be spilled at fueling stations, and may be improperly disposed of instead of being taken to recycling stations.

Improper disposal includes dumping directly to a storm water sewer pipe materials, and dumping on the ground, where the material may drain directly to a storm sewer or be washed into a storm sewer during a sto event. Rain and snowmelt can also carry these pollutants directly to adjacent surface waters.

Runoff in storm sewers is usually carried to a wastewater treatment plant with other sewage. These wastew treatment plants treat water to remove conventional pollutants such as oil and grease. During heavy storm events, the quantity of stormwater runoff entering sewers can overwhelm treatment plants. These heavy stormwaters bypass the treatment plant and are discharged without treatment. This untreated discharge cont many contaminants, including waste oil.

Effects of bad and illegal plumbing: Studies have shown untreated storm water sewer discharges often include wastes and wastewater from *non*-storm water sources, commonly referred to as **illicit discharges**. These discharges are ``illicit" because the storm sewer systems are not designed to accept and discharge, or t process, such wastes. These discharges require government permits under the Clean Water Act. As a result, illicit discharges to storm sewer systems can create severe widespread contamination and water-quality problems.

Example: Michigan study on improper disposal of oil products by commercial facilities



The Ann Arbor and Ypsilanti municipal water qual projects in Michigan inspected 660 businesses, homes, and other buildings and identified **14 perce** of the buildings as having improper storm sewer dr connections. The program assessment revealed that on average, **60 percent** of automobile-related businesses, including service stations, automobile dealerships, car washes, body shops, and light industrial facilities had illicit connections to storm sewer drains. The program assessment also showed that a majority of the illicit discharges to the storm sewer system resulted from improper plumbing and connections, which had been approved by the municipality when installed. (Huron River Pollutio Abatement Program, Washtenaw County Statutory Drainage Board, 1987.)

Effects of actions by private citizens: Improper disposal of materials to street catch basins and other storm sewer inlets often occurs because many people mistakenly believe that disposal to such areas is an environmentally sound practice. Part of the confusion may occur because some areas are served by combine

R0026337

sewer systems, which are part of the sanitary sewer collection system, and people assume that materials discharged to a catch basin will reach an appropriate municipal sewage treatment plant; however, very few places in the United States actually treat their storm water. The vast majority of storm water sewers discharg effluent directly to surface waters.

The materials that are most commonly dumped on the ground or in storm sewers by the general public inclu

- used oil,
- household toxic materials,
- radiator fluid, and
- litter (disposable cups, cans, and fast-food packages).

Table 2. Percentage of respondents that reported disposal, in the past 12 months, of motor oil, paints, or chemicals at (a) county collection sites; (b) local service stations; (c) into sewer or storm drains.

	Number of Respondents	County Collection Sites	Local Service Stations	Sewer or Storm Drains
Total Number of Responcents	~200	90+	70+	approx. 40
Percentage of Total	+ + 100%	45%	35%	20%
County A	+ 60	67%	25%	8%
County B	+ 75	27%	53%	20%
County C	+ 65	31%	38%	31%
One-Person Household	+ 35	43%	43%	14%
Two-Person Household	+ 65	38%	39%	23%
Three-Person Household	100	50%	30%	20%
Owners	120	67%	25%	~ 8%
Renters	+ 80	13%	50%	37%

Source: http://www.epa.gov/owowwtr1/OCPD/ex_6-5t.html, *Measuring Progress of Estuary Programs* (EPA 1995)

Through recent community-level initiatives such as recycling and household pickup programs there h been increasing success in addressing these problems. (See Community Activities) The EPA seems increasingly aware that this is a necessary approach to deal with the problem of oil-polluted storm-wa runoff. When the general public is the main polluter then the traditional approaches developed mainl for industrial pollution are not sufficient. More on alternative approaches in the final section.

How much oil is in stormwater runoff?

R0026338

It is extremely difficult to quantitatively distinguish the individual impact of oil products from the impact of the rest of the set of storm water pollutants. From toxicological data, EPA estimates that oi products constitute one of the most damaging group of pollutants in urban runoff in the US. (EPA 19 Document code fr09ja98-23).

A lot of oil can enter surface waters through stormwater runoff:

- During one four-hour storm, 24,000 gallons of oil and grease, equivalent to a moderate crude oil spill bypassed New York City's Newton Creek treatment plant.
- A study of Jamaica Bay, New York, found that 50% of the petroleum derived materials contributed tc bay are due to wet-weather overflows. The major source of petroleum contamination in Jamaica Bay shown to be waste crankcase oil. This is in agreement with studies of Delaware Bay. Petroleum hydrocarbons and associated aromatic hydrocarbons are a cause of serious ecosystem degradation in New York Bight. Accumulation of polynuclear aromatics in sediments eventually may prove harmful benthic communities in the Bight.

Used oil as a major pollutant: According to a recent study conducted by the National Research Coun the largest source of petroleum-related pollution of water has been identified as storm water runoff (Sierra Magazine, March 1999). This graph was compiled from a diagram based on figures from the National Research Council (and published in Sierra Magazine April 1999) to illustrate the proportion oil pollution from road runoff and oil changes.

Leading sources of water quality impairment nationwide identified in a 1998 report by EPA include non-point and diffuse sources (i.e., urban storm water runoff--runoff from agricultural and urban sources, construction sites, land disposal of waste, and resource extraction), industrial process wastewaters, and municipal point sources.

Table 3. Leading sources of pollution for particular water bodies in the US (EPA1995)

Water Bodies	Urban runoff	Resource extraction	Waste disposal
Rivers/streams	12%	11%	
Lakes/reservoirs	18%		11%
Estuaries	46%		13%

The measured amounts of pollution from diffuse sources, including storm water runoff from agricult and urban sources, construction sites, land disposal of waste, and resource extraction indicate that diffuse sources are a leading cause of impaired waters, as follows (see table 2): The table should be interpreted as follows: Out of all rivers and streams surveyed, twelve percent of them were impaired l urban runoff/storm sewers as their main non-point source of pollution, and 11 percent were impaired resource extraction. Similarly, eighteen percent of the studied lakes, ponds, and reservoirs ere impair by urban runoff/storm sewers, and 11 percent were impaired by land disposal of wastes. Forty-six percent of estuaries were impaired by urban runoff/storm sewers, and 13 percent were impaired by la disposal of wastes.

TOP OF PAGE

R0026339

Home | Glossary | References

V625 Environmental Economics and Policy, Spring '99, Dr. Kenneth Richards ,

Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

R0026340

Economic Damages

Home | Glossary | References

Economic Damage and Abatement Costs

ECONOMIC DAMAGE   ECONOMIC BENEFITS OF ABATEMENT

Economic damage of uncontrolled oil-polluted surface runoff

Loss of ecological services: Water polluted with oil damages aquatic and wetland ecosystems by degrading habitat and harming plant and animal populations. Many of the richest and most ecologically productive habitats occur at the edges of water--along the banks of rivers and streams and along the shores of lakes and oceans. Pollution of these waters can have negative effects on the ability of aquatic and wetland habitats to perform their functions in the ecosystem. These ecological functions can be thought of as services that the ecosystem provides.

By considering ecological functions as *services* they can then be associated with a value. One way to value these services is to find the commodity value of resources extracted from the ecosystem, for instance, the value of a commercial fishery. Another valuation method for ecological services is finding the value of a man-made substitute for the service. For instance, the water purification service of an acre of wetland may be valued at the cost that industry, agriculture, and municipal water suppliers would incur to perform the filtration themselves. Costanza et al. (1997) used both of these techniques in their calculation the value of global annual ecological services. They estimated that the 530 million acres of rivers, streams, lakes, and wetlands provide combined ecological services of $6.58 trillion.

Cost of clean-up: The costs of cleaning up major tanker disasters can be very, very high. For instance, the cleanup for the 11 million barrels of oil spilled by the Exxon *Valdez* has cost nearly $4 billion in environmental and legal damages.

Cost of lost recreational opportunities and asthetics: Oil pollution of aquatic ecosystems kills fish and poisons waterfowl. Oil-polluted water can also have an unpleasant odor and may have a film of oil at the surface. These effects combine to damage the recreation possibilities in an on oil-polluted waters, as well as making them unattractive. The cost of oil pollution in these inland waters can be measured as the damage to sport fisheries (which have been valued for marine systems, see EPA 1992) and waterfowl hunting as well as decreases in property values for properties adjoining or containing oil-polluted waters.

R0026341

Economic benefits of abating oil-polluted surface runoff

The economic benefits of abating oil pollution in inland surface waters are the avoided replacement costs for ecological services and the value avoided damage to natural resources commodity production. In other words, oil will not have to be removed from intake water by downstream industrial, agricultural, and municipal users, and commercial fisheries will retain their value. Additionally, recreational opportunities will persist and clean-up costs will not be incurred.

People pay a premium to live near clean water, and one of the technical options for addressing non-point source runoff pollution of surface waters both improves existing waterways and creates new waters. Stormwater retention ponds and constructed wetlands are both recommended as best management practices to control this contaminate. These ponds and wetlands filter out oil and encourage biodegradation and other forms of breakdown, which improve the quality of receiving waters. In addition, these artificial ponds and wetlands can have additional positive impacts on property values (up to $60,000, Frederick et al. Date unknown).

TOP OF PAGE

Home | Glossary | References

V625 Environmental Economics and Policy, Spring '99, Dr. Kenneth Richards ,

Group 7: Krister Andersson, Katherine Ardizone and Laura Hilden

R0026342

Analysis

Home | Glossary | References

ANALYSIS and RECOMMENDATIONS

We have seen that non-point source waste oil pollution of surface waters causes economic and environmental damage. This pollution comes from numerous and diverse non-point sources, which have unique physical and regulatory properties. Because of these unique features, it is not practical to impose emissions charges or to use other emissions-based economic incentives for abatement. It is also unrealistic for any federal regulation to encompass all aspects of petroleum non-point source pollution. Even detailed and thourough legislation calls upon the need for public understanding and participation to address this issue effectively. Although the Clean Water Act is a good beginning, it is not comprehensive enough to remedy oil pollution problems on its own.

Command and control regulation can be used to require best management practices (BMPs) but these measures can only accomplish some abatement. Economic incentives should focus on markets for used and waste oil. As the current situation for the used oil markets is unstable, the incentive for new waste reduction and recycling technologies lies in the economic benefit of conserving oil.

Non-point Source Pollution

Non-point sources demand non-traditional approaches

On the previous pages on this web site, we have seen how the problem of oil pollution in US surface waters is closely linked to inappropriate consumer practices, such as illicit discharges and leaks from deficient motor vehicles. As shown in a 1998 report by the National Research Council, the most important source of oil-related water pollution is motor oil in storm water runoff - commonly washed off from oily parking lots or dumped directly into the storm sewers by ignorant car owners. These pollution-source characteristics pose a particular challenge to policy makers when trying to come up with an effective government regulatory response. As a government agency, how do you enforce a policy that aims at regulating the way millions of Americans handle used motor oil?

EPA's command and control policy instruments were primarily developed to curb industrial sources of pollution. Applying the same uniform standard approach to regulate non-point source oil-pollution of surface water is likely to have little effect and run into tremendous enforcement problems when applied to a non-point pollution problem. The EPA knows this and has therefore introduced programs such as the National Pollutant Discharge Elimination System (NPDES), which incorporate criteria for Best Management Practices (BMPs) for different actors.

Why the Clean Water Act is Not Enough

Water pollution control has come a long way in the US since the Cuyahoga River burst into flames 30 years ago. The Clean Water Act of 1972 should get most of the credit for accomplishing the observed improvements, but the command and control approach of the Clean Water Act can only take us so far. It may have been effective in curbing industrial discharge and other point sources of pollution, but the uniform standards approach has done little to reduce pollution from non-point sources (NPS) of inland surface waters. Non-point sources, however, remain a major problem for inland surface waters -- and for policy makers.

Why BMPs are Not Enough

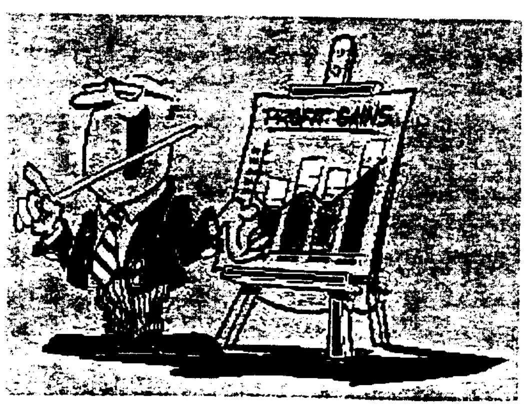
We believe that the EPA initiative to include Best Management Practices in the mainstream EPA non-point source programs represent an important step in the right direction for government interventions, especially when dealing with municipal non-point sources and agricultural runoff. The initiative recognizes the important role of local resource users and the decisions they make resource use.

These EPA programs are insufficient for controlling the most common non-point source of oil pollution in surface waters in the US - the millions of regular American individuals who handle motor oil on a daily basis. We cannot expect NPDES and similar programs to have any significant effect on oil-polluted storm water. Any command and control-based regulation - even if combined with BMPs - is doomed to fail when it is directed towards millions of individual American consumers. It would be unrealistic (and extremely costly) to enforce such a policy because the EPA cannot acquire complete and perfect information about the full extent of motor oil pollution of surface waters.

Although states have been given responsibility for implementing these NPDES permits, most states do not have the resources to monitor NPS pollution, which means that they can't find some of the less obvious hot-spots that contribute to pollution. The data collection programs that states have are usually designed to monitor point sources. While much NPS pollution may enter receiving waters from facilities that are also point sources, the monitoring equipment may not be set up to detect these different pollutants. The lack of state monitoring programs makes it impossible to measure the success of BMPs in controlling NPS pollution.

If imperfect information leads to limited and sporadic enforcement, then we can also expect low compliance as a likely policy outcome. Consequently, we can conclude that current legislation - even in combination with widely applied BMPs - is not enough to reduce oil-pollution of inland surface waters in the US. The present situation calls for new, complementary approaches that can better address the particular characteristics of oil our problem scenario.

Problems with the Used Oil Market

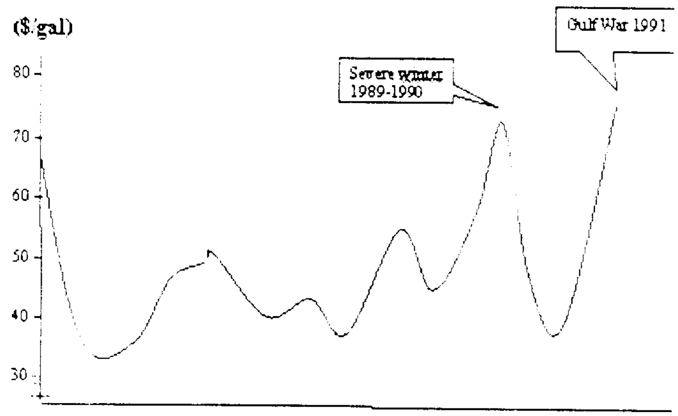


One of the major limitations for the used oil market is the direct impact the price of virgin oil has on the profit margin for recyclers. In order to compete, recycled oil products must be sold at a lower price than virgin oil products (Nolan in EPA 1994). In addition to pricing products below crude oil, recyclers bear the burden of collection costs while trying to maintain a profit. This can be especially problematic for recyclers when virgin oil prices are low.

R0026344

Figure 3. The effects of virgin oil prices on payments made t generators for used oil (EPA adaptation of Nolan et al. 1990

When virgin oil prices dipped below roughly $.50 per gallon, the generators of used oil experienced a loss from $.01 - $.10 per gallon of used oil. The area between the red and blue regions represents a free zone; no payment, no charge. Only at levels indicated by the green figures was it profitable to be used oil generator.



When prices for virgin crude are high, there is a stronger incentive for used oil processing and re-refining because recyclers and transporters will pay for it. Conversely, low virgin oil prices encourage onsite burning of used oil (EPA 1994). Because the value of virgin oil has fluctuated dramatically in the last decade, it is very difficult to create a stable used oil market.

Complementary Incentives for Increased Compliance

We do not argue that the US government should give up its command and control approach and the Clean Water Act and have it replaced by market-based policy instruments. We believe that the CWA is a good base for controlling a dangerous contaminant such as motor oil and that it should be taken further.

We argue that if the US government is serious about reducing oil-pollution of surface waters, then BMPs should be taken further and linked to a series of complementary market-based incentives. The goal of these market approaches is to create a market for waste oil that will make used oil too valuable to waste. Introducing a motor oil tax or a deposit/refund incentive would create incentives for DIYs to keep track of oil and will create incentives for commercial used oil generators to comply with BMPs. EPA proposed these and other market incentives in 1991 but have not put them into place. These market-based approaches, which rely principally on a self-regulating price mechanism to achieve a socially optimal market equilibrium, should reduce the need for the government to acquire perfect information and thus lower the costs of monitoring and enforcement.

Recommendations

Based on the above analysis, we would like to urge policy makers and all other motor oil users to consider and support the following steps for immediate action:

R0026345

- 1. Extend the current NPDES instrument for storm water runoff control to include all the major actors associated with oil-pollution storm water and develop appropriate BMPs for the expanded NPDES program. Although it is difficult to measure the direct environmental impact of such measures, it is nevertheless an important step to take.

  2. Introduce market incentives to achieve higher compliance for BMP standards for individual users. We specifically would urge policy makers to consider a policy mix consisting of a combination of some or all of the following instruments:
- A product tax on motor oil as to achieve a socially optimal market equilibrium and to raise revenue to finance incentive programs;
- A deposit/refund system on motor oil as to provide a direct cash incentive for user to recycle the used oil through an authorized agent;
- A price floor for virgin oil as to make recycling of used oil more profitable;
- A series of economic incentives to promote appropriate BMPs associated with private consumers' handling of used motor oil, such as providing opportunities for training and technical assistance on BMPs and introducing small grant programs to support the development of innovative local responses to address the used-oil problem at the neighborhood level;
- Tax incentives for petroleum and other related industry companies that engineer new products to efficiently manage new and used oil.

3. Expand the current efforts to inform the public about the adverse effects of illegally dumping used motor-oil into the street sewers, and

4. Conduct more studies on the economic damage of oil pollution of US surface waters, so that a quantitative benchmark can be established against which new policies can be evaluated.

In light of economic and environmental considerations, we feel these approaches to addressing the problem of surface run-off petroleum pollution would prove effective in significantly reducing the amount of oil in our waters. These recommendations are in no way the only instruments that may be employed to address this issue. By revising government regulation, market practices and public perception, the problem of oil pollution may be less threatening to human health and the environment.

Home | Glossary | References

V625 Environmental Economics and Policy, Spring '99, Dr. Kenneth Richards ,

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R0026346

Southern California Environmental Report Card 1999

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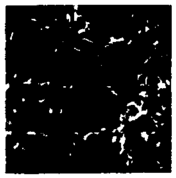
Contents

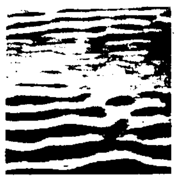
2 From the Editors

3 Letter From the Director

4 Wildland Fire



Stormwater Impact 12



22 Groundwater Quality

Environmental Education 32

38 About the UCLA Institute of the Environment

41 RC 1998 Revisited

From the Editors

The Southern California Environmental Report Card is produced once a year by UCLA faculty under the sponsorship of the UCLA Institute of the Environment. Each issue contains several articles addressing critical environmental concerns facing the fourteen million people in the Southern California region. The goal of every article is to provide an introduction and background to the science and policy, describe the current situation, and then evaluate in a balanced manner relevant performance of the public and private sectors, and the general public, in meeting the challenges of that particular environmental concern.

The environmental issues addressed in each Report Card will rotate over time. While the dominant environmental problems of the region dictate that various aspects of air and water quality will be ongoing themes, other important environmental topics will also be addressed. For example, in the first Report Card published last year (RC 1998), one of the articles discussed the state of wetlands in Southern California. In this year's Report Card (RC 1999), one article considers the impact and control of wildfires. Another assesses the state of environmental education in primary and secondary schools.

While faculty who write for the Report Card are all experts in their fields, they represent a wide range of academic disciplines, including social science, natural science, law, public health, engineering, urban planning, public policy, and others. Since environmental issues do not come neatly packaged by the usual academic disciplines, it is appropriate that the Report Card present a multidisciplinary perspective. But all of the authors share a common desire to draw on the best scholarship possible in order to help inform local and regional policy discussions.

The environmental problems facing Southern California are complex, and rarely are there simple solutions on which all stakeholders can agree. Therefore, each Report Card in the future as well as the present one will include reactions from knowledgeable commentators on the content of the articles from previous years. Our aim is to foster informed dialog from different points of view. In that spirit, we welcome constructive responses, whether in agreement or contradictory, from any readers who wish to share their views. All of us in Southern California have a stake in working together to find cost-effective and socially acceptable solutions to our major environmental problems.

Richard Berk, Ph.D.
Departments of Statistics and Sociology

Arthur M. Winer, Ph.D.
Department of Environmental Health Sciences

Editors, IoE Report Card

Letter from the Director

This is our second annual Southern California Environmental Report Card (RC 1999). It follows last year's Report Card (RC 1998) which was a great success, judging from the many positive responses we received from decision-makers, faculty, students and the public. Some of the responses we received from agencies are given in a final section (see RC 1998 Revisited) including an account of an important success story concerning wastewater treatment. In this year's Report Card we discuss Wildland Fire, Stormwater Impact, Groundwater Quality, and Environmental Education. All of these affect our local environment and have national implications as well. The grades range from "B" to "F."

Our objective in this and future Report Cards is to focus attention on environmental issues that affect the quality of our lives. We hope to issue a "call to action" when there are problems, as well as recognize decision-makers and the public when credit is due. In this edition of the Report Card, we have a mixed record of successes and failures. We also suggest actions that can be taken to further improve the environment.

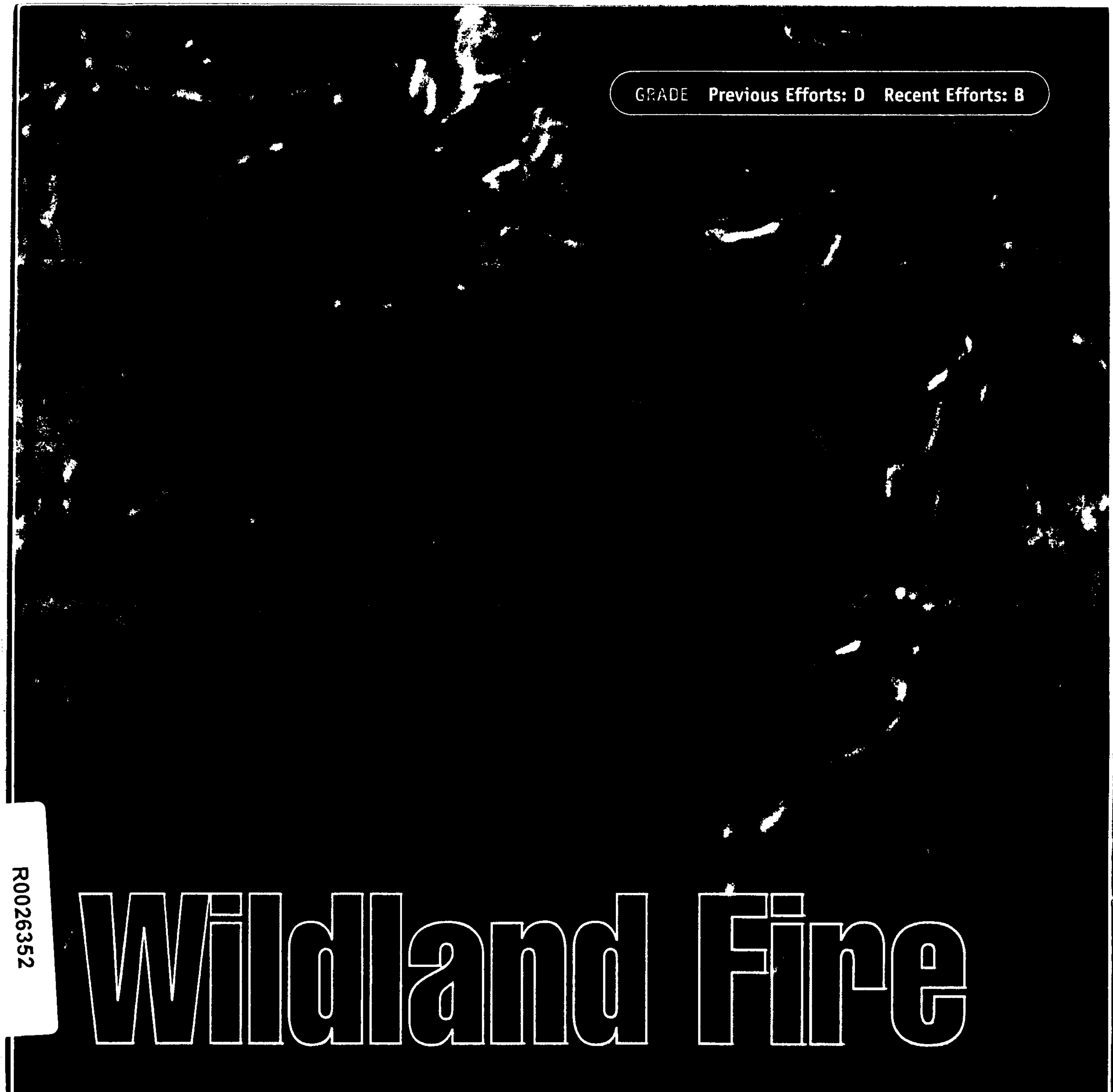
As discussed in more detail by our Editors, we hope each Report Card is an accurate, unbiased and understandable account of environmental issues. We believe individuals, agencies and advocacy groups will find the report useful. Each section of the Report Card represents the assessment of an expert in the respective field, and has also been reviewed by senior faculty and others who have broad and penetrating knowledge. Still, we do not expect everyone will agree with all points of these articles. We welcome your responses and comments.

It has been a busy year for the UCLA Institute of the Environment (IoE). Within the Institute, we are practicing an increasingly more popular method of performing research. The complex problems we face are institutional as well as technical. Their solution requires more than a single discipline. Our approach is to integrate research among many disciplines. The Institute represents more than 50 professionals with knowledge spanning environmental fields from 20 different disciplines.

An example of this way of performing research is the Santa Monica Bay Watershed Project "Integrated Urban Watershed Analysis: The Los Angeles Basin and Coastal Environment," an NSF/EPA-sponsored grant. In this project, we are developing a more comprehensive understanding of Santa Monica Bay. Our scientific teams are studying pollutant inputs from all sources, including atmospheric, stormwater, point sources and the ocean itself. We are also studying the transformation and fate of the contaminants within the Bay. Meteorology, both short and long term, is important for this understanding. We recently held a one-day symposium at UCLA with invited guests from agencies responsible for managing activities that affect the Bay. Next year, we will have a second symposium to present our final findings. These results will lead to a greater understanding and new management tools to better protect Santa Monica Bay.

We look forward to your comments and hope you find this year's Report Card useful.

Michael K. Stenstrom, Ph.D., P.E.
Director 1998-1999
Institute of the Environment



GRADE **Previous Efforts: D** **Recent Efforts: B**

Wildland Fire

by Philip W. Rundel, Ph.D.

Professor, Department of Organismic Biology, Ecology and Evolution

Fire is an inevitable and periodic disturbance in the southern California landscape. The seasonally dry Mediterranean climate, coupled with the presence of flammable chaparral communities in the urbanized wildlands of the mountain areas of Southern California, make wildfire one of the most serious economic and life-threatening natural disasters faced by the region. The long summer drought in our Mediterranean climate results in a pronounced fire season that extends from summer into fall and even into January in unusually dry years. Why does chaparral burn so intensively? These woody shrubs dry considerably during the summer months, and small twigs and dead grasses provide flammable kindling to help a fire ignite. Volatile oils produced by several common species increase the ease of igniting a fire.

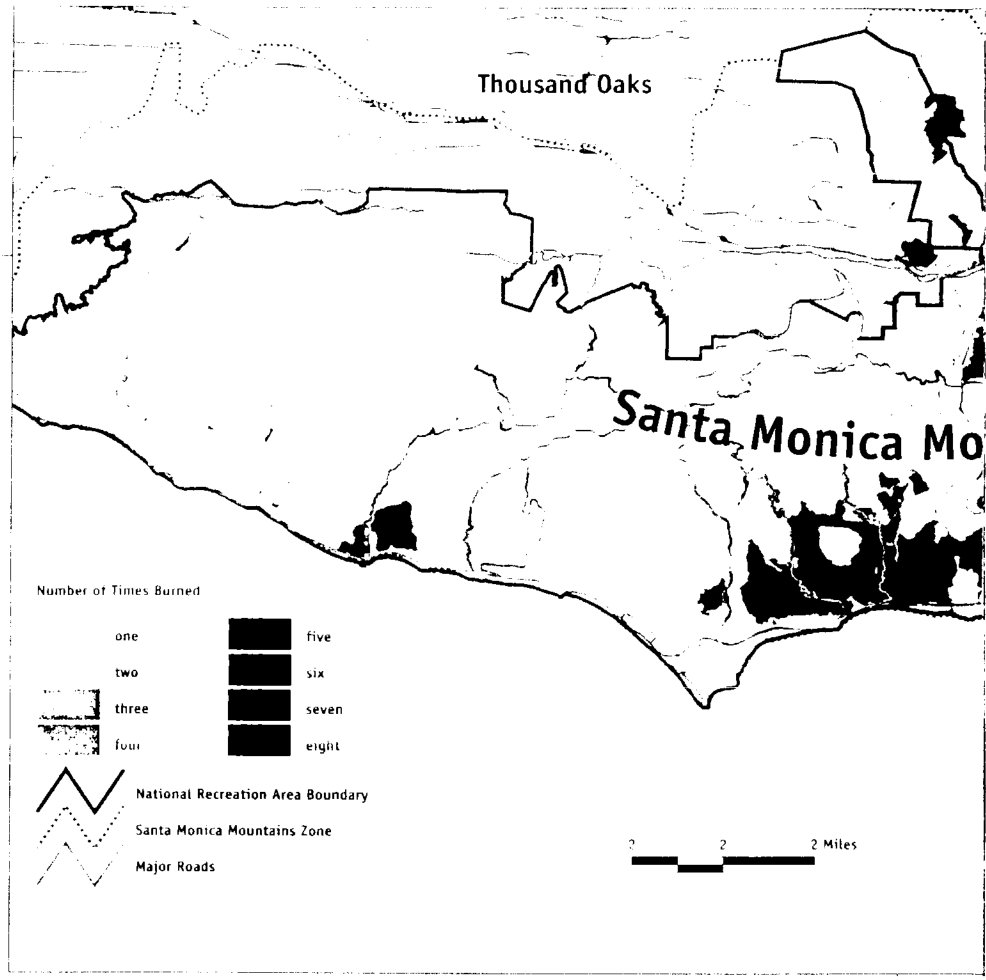
While the cause of chaparral fires was once rare lighting strikes in late summer, most fires today have a human origin through ignitions or regrettable deliberate actions. Human ignitions of fire are far from a random event, and instead occur with predictable high frequencies along specific road corridors. In the Santa Monica Mountains, for example, the [illegible] that [illegible] Ventura Freeway or the urbanized corridor of Mulholland Drive at the northern margin of the range.

The danger of wildland fire spread from many such sites is magnified greatly in the fall and early winter when strong and dry Santa Ana winds from the inland desert blow into Southern California. As these winds funnel through canyons in the transverse and coastal ranges of Southern California, wind speeds increase dramatically. Such winds, coupled with relative humidities that may be as low as 2%, can push firestorms through our foothill regions with alarming speeds and intensities.

Fire, however, is a natural process in our mountains and existed long before human populations arrived. Furthermore, fires perform important ecosystem functions necessary for the healthy maintenance of chaparral and woodland communities. This concept of fire as a natural component of our region is clearly indicated by the remarkable adaptations that exist in our chaparral communities to thrive under fire conditions. Fire, for example, is necessary for the reproduction of many chaparral plant species, and these species exhibit a variety of adaptations for re-establishment after fire, through resprouting from their woody root crowns and germinating new individuals from seeds stored for many years in the soil.

Annuals and short-lived woody species, whose seeds may have lain dormant in the soil for 50-100 years or more, become established in the first spring after a fire and help to stabilize soils against erosion and hold nutrients that might otherwise be lost. The diversity of chaparral species is highest in the first year after fire, and declines as the dominant chaparral shrubs become re-established.

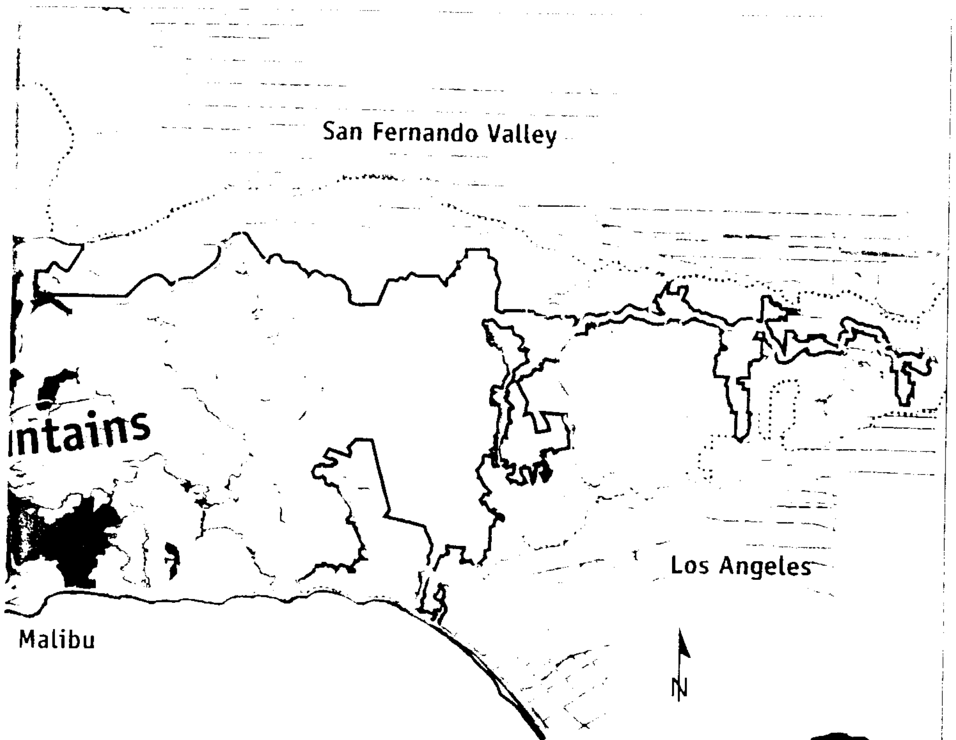
Fire history of the Santa Monica Mountains, showing the number of wildfires that occurred for the range between 1925 and 1997. Note that the Central Malibu coast has received 6-8 fires over this period compared to much lower frequencies to the west and east.



Surprisingly, most animals in chaparral habitats also survive fire very well. Small animals such as snakes, pocket gophers and mice can survive nicely in underground burrows, while larger animals such as deer, coyotes, and bobcats will flee in front of an advancing fire. It is only the intermediate size animals such as small rabbits and woodrats with their stick nests that suffer from fires because they are too large to go underground but not sufficiently agile to flee.

The question of what is a "normal" fire frequency in chaparral and coastal sage scrub has been the subject of considerable debate. Typical estimates range from 30 to 50 years between fires, but in reality we have little knowledge of what such frequencies were prior to this century. Human activities have obviously affected natural fire frequencies. Fire was widely used by Native Americans in Southern California as a tool for maintaining wildlife habitat and for encouraging certain utilitarian plant species. From colonial Spanish times to the current century fire was frequently used by European and Mexican settlers to clear shrublands for farming and cattle ranching.

In recent decades, heightened human activity and arson have increased the fire frequency in some areas, particularly regions close to development and roads. Conversely, current policies of fire suppression that date back 75 years or more have reduced fire frequency in other areas. The irony of fire suppression is that it may have increased the likelihood of catastrophic fires by allowing large masses of flammable plant materials to accumulate with time. This process is reinforced when chaparral canopies suffer an extensive dieback of living tissues, as occurred, for example, during the long drought period from 1987-1993. Fire suppression has occurred at the same time there has been an increased penetration of urban development into chaparral vegetation, and thus increased danger to structures and human lives from wildfires.



FIRE HISTORY 1925 – 1997
Number of Fires Since 1925
Santa Monica Mountains National Recreation Area

NATIONAL PARK SERVICE

The question of what is a "normal" fire frequency in chaparral and coastal sage scrub has been the subject of considerable debate.

FIRE AT THE URBAN/WILDLAND BORDER

The Southern California wildfires of 1993 and 1996 illustrate the dimensions of this problem from a human and urban perspective. Within a two-week period during the Fall of 1993, large parts of the foothill areas of Southern California erupted into flames. Within the Santa Monica Mountains, the Green Meadows and the Old Topanga fires of 1993 raced a linear distance of 25 km within a few hours, consuming a combined area of more than 50,000 acres before stopping at the Pacific Ocean. More than 21 major fires over these two weeks burned through 200,000 acres of chaparral and oak woodland, destroying more than 1,000 homes. Financial losses in the greater Los Angeles area during this period were estimated to be over $1 billion dollars, exceeding the property damage associated with the 1992 Los Angeles civil unrest. Four people died and 162 individuals suffered significant injuries. Added to this cost is subsequent damage from mudslides when heavy rains eroded bare hillsides.

Overall, more than 15,000 fire fighters from every county of California, and all of the western states joined to fight these fires, arguably making this the greatest mobilization of fire fighters in the history of the world. These events were repeated in the fall of 1996, when another fire erupted in the city of Calabasas and followed a similar pattern, burning uncontrollably across the Santa Monica Mountains until it reached the Pacific Ocean. This time, however, a rapid mobilization of fire fighters, a lower population density of homes, and improved levels of clearance around homes built with less flammable materials all combined to greatly reduce the level of property damage.

Throughout much of the Southern California region the buildup of fuels in remaining unburned areas make it inevitable that large areas will burn in the future. Large fires, driven by Santa Ana winds, will burn through vegetation of any age and are

Following chaparral fires, the living vegetation cover is totally burned, leaving only dead shrub skeletons and an ash layer. Most of these shrubs will quickly resprout, however, from underground buds.

Ongoing studies of fire behavior and ecology are providing important insights into the environmental role fire plays in chaparral and woodland ecosystems of Southern California.

exceedingly difficult to control. Without effective management policies and appropriate control on the nature of development, the loss of structures and human life will be an unavoidable consequence of intensive urban and suburban development in zones of flammable vegetation. The continued pressure to expand the urban fringe, and the continued difficulty of managing remaining chaparral fragments within the complex mosaic of land ownership in this area, ensure that fire will continue to be an important policy concern for the human and natural environments of our region.

The combined influence of increasing building regulations (e.g. less flammable building materials, shielding of overhanging decks, wider driveway access, water availability) and the encouragement of brush clearance and low flammability landscaping have done much to reduce danger to individual homes in the foothill areas. Newer homes built under such requirements are significantly less likely to burn than are older homes with flammable roofs and narrow driveways that restrict fire department access.

FIRE BEHAVIOR

Ongoing studies of fire behavior and ecology are providing important insights into the environmental role fire plays in chaparral and woodland ecosystems of Southern California. We know, for example, from 75 years of records that the central coastal areas of Malibu in the Santa Monica Mountains are subjected to far higher frequencies of fire than areas to the west and east. Such knowledge of past fire behaviors and extent are of great value in helping to develop mobiliza-

Fire management in the Santa Monica Mountains and the Los Angeles Basin has developed as a cooperative effort involving many government agencies.

The interfingering of urban development and wildlands in Southern California puts homes at potential risk from chaparral fires.

tion plans to fight future fires in the most effective manner. At the same time, these studies are raising many new questions.

If natural fires were largely ignited in the past from late-summer lightning strikes in August and September, these fires would typically have occurred before the onset of Santa Ana winds. The majority of such fires would be expected to have been low in intensity and relatively small in size. Such fires would produce natural mosaics of chaparral stands of differing ages. Central and northern California are shielded from Santa Ana winds by the Sierra Nevada and as a result have fewer large fires. However, if the seasons of natural fires in Southern California extended into the fall and were influenced by Santa Ana winds, then large catastrophic firestorms may be more typical of our landscapes. We lack the knowledge of fire histo-ies before this century to adequately resolve his question.

FIRE MANAGEMENT POLICIES

Fire management in the Santa Monica Mountains and the Los Angeles Basin has developed as a cooperative effort involving many government agencies. These include the Los Angeles City and County Fire Departments, California Division of Forestry, Ventura County Fire Department, National Park Service, USDA Forest Service, and California Division of Parks and Recreation. The active fire management policies of these agencies have been focused on goals of reintroducing fire as a natural ecosystem process to the degree possible, consistent with the safety of human lives and property, and reducing the amounts of hazardous chaparral fuels present through the use of prescribed burns under controlled conditions. While the cost of active fire management activities is substantial, it is far less in the long-term perspective than the consequent costs of property damage resulting from extreme wildfires. Much of the effort on fire management through prescribed fires is being focused on key areas where historical data suggests such program can be of significant help in reducing fire intensities in areas where fires commonly begin or where moving fires can be controlled.

Fire management policies have led to a number of controversial issues that have now largely been resolved. Early fears of liability issues for property damage associated with prescribed fires have now been surmounted by a California State program of indemnification for fire management agencies which carry out prescribed burns under what are termed *Best Management Practices*. Without indemnification, such prescribed burns would not be allowed.

Prescribed burning presents an effective means of reducing fire hazards in key areas. This technique reduces the build-up of flammable fuels through controlled fires carried out under conditions when fire intensities remain low and controllable.

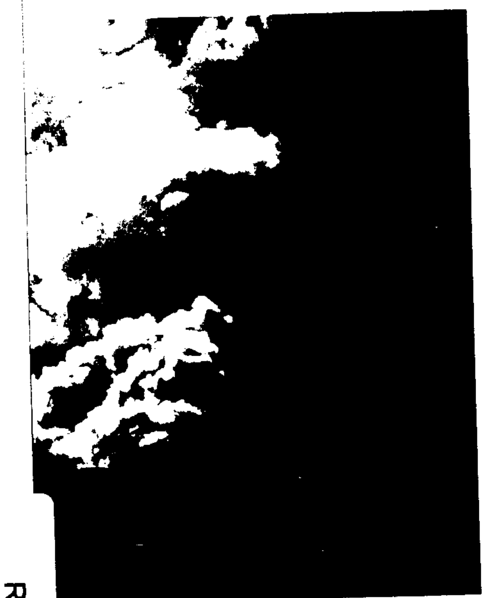
Another example of long-standing controversy resulted from a policy of active post fire reseeding with rye grass or other grasses. This has been a prevailing management practice for many years. The practice continued up until this decade despite a high cost and scientific studies indicating that such seeding offered little or no positive value in erosion control and impaired the ability of the native shrub and herb cover to become reestablished.

Brush clearance regulations remain another issue of contention as increased awareness of fire hazards in the foothill areas has led to more stringent city and county regulations on brush clearance around houses at the urban/wildland boundary. The potential for reduced homeowner's insurance rates through the California Fair Plan program has provided a strong financial incentive to comply with these regulations. Nevertheless, policies on recommended brush clearance practices and distances vary among agencies. There has long been an issue of the impact of new home construction along the boundaries of existing parkland where clearance setbacks extend into these public lands. New regulations now allow the Fire Department to review site plans for homes in the Santa Monica Mountains and many other foothill areas to encourage 200-ft setbacks of new homes from parkland boundaries.

Still other issues remain. In particular, the potential impact of prescribed burning on air quality has led to unresolved problems in evaluating the benefits of chaparral fuel reduction against the consequences of increased particulates in the atmosphere from smoke. Additionally, we still lack an understanding of the natural frequencies and intensities of chaparral fires before the arrival of human populations in Southern

Fire management policies have led to a number of controversial issues that have now largely been resolved.

California. Scientific studies are now using the latest in electronic and remote-sensing technology to permit better predictions of the frequency, intensity and rate of spread of wildfires. However, more improvements are needed.



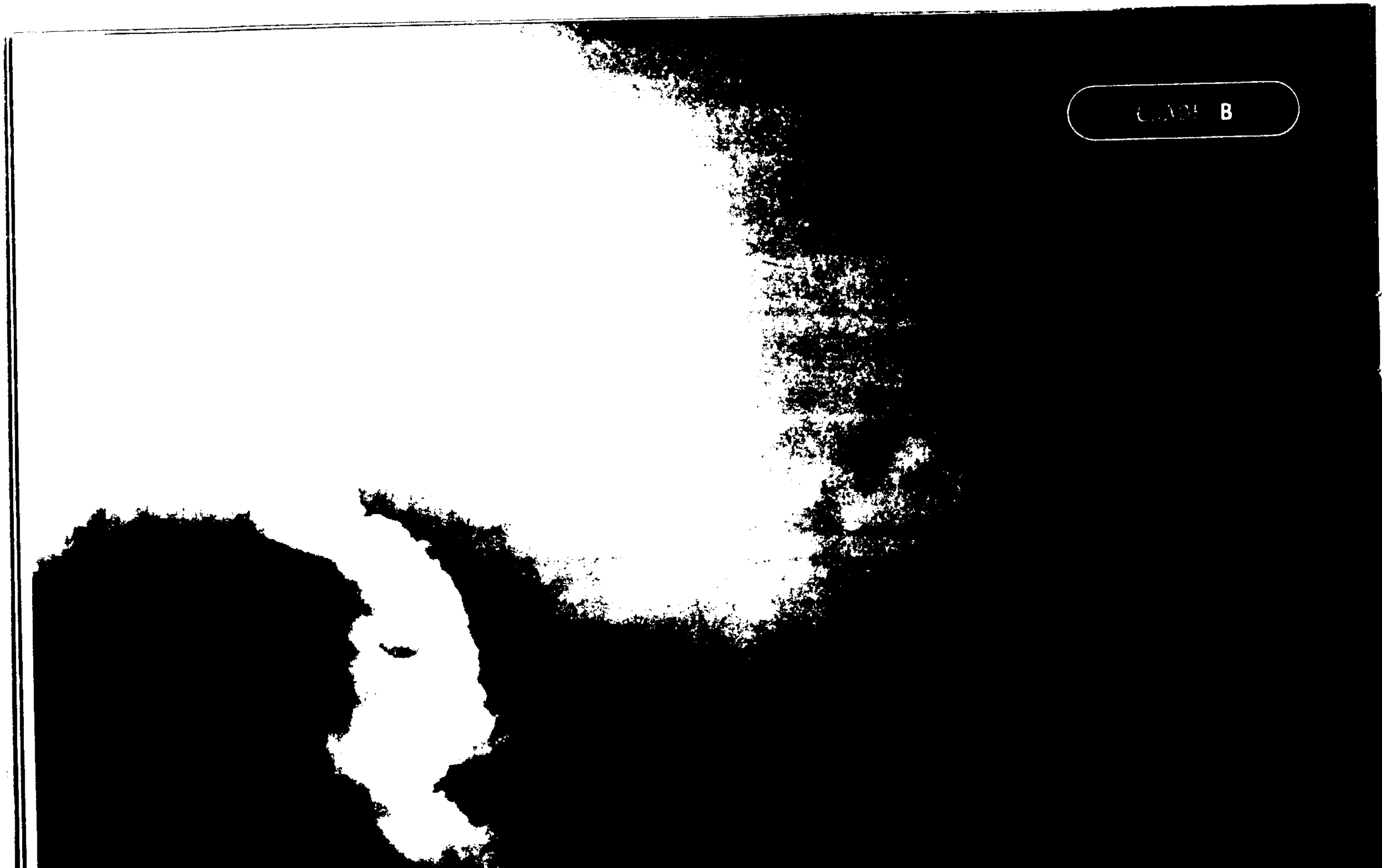
Prescribed chaparral burns create a management dilemma in that they reduce fire hazards but add smoke particulates which negatively impact air quality.

FIRE MANAGEMENT ASSESSMENT AND THE GRADE

The nature of fire management practices in the Los Angeles Basin and Santa Monica Mountains have shown significant improvement over the past decade. **Our previous efforts in wildland fire management deserve a "D".** A key to this progress has been the success of the Fire Alliance program that has brought together government agencies and private stakeholders (e.g. property owners and the insurance industry) to work cooperatively to develop the most appropriate policies for managing natural resources while protecting people and property from wildfires. This level of successful cooperation has been a model for other government/public programs.

In recent years, our overall program of wildland fire management has improved markedly, and now earns a rating of "B".

Philip Rundel is Professor of Biology in the Department of Organismic Biology, Ecology and Evolution at UCLA. He has been a faculty member in the University of California since completing his Ph.D. at Duke University in 1969. He has worked on a variety of studies of fire ecology and fire management in chaparral ecosystems and in mixed conifer forests in the Sierra Nevada. More broadly, his field of research investigates aspects of the adaptations of plants to environmental stress in Mediterranean-climate regions. He has actively worked with ecological studies of chaparral and related shrublands and woodlands in California, central Chile and the Cape Region of South Africa. Expanding beyond chaparral systems, he has also worked on a variety of programs related to the ecology and conservation biology of tropical regions around the world. This work has involved projects in Thailand and Indochina, Costa Rica, Brazil, Zimbabwe and the high Andean Altiplano region of Peru and northern Chile. In addition to his regular faculty duties, he is the manager of the UCLA Stunt Ranch Reserve, a field station for education and research in the Santa Monica Mountains.



B

Stormwater Impact

by Michael K. Stenstrom, Ph.D., P.E.

Professor and Chair, Department of Civil and Environmental Engineering

Coastal waters are one of our most important natural resources. Coastal water quality is the natural resource that gives Southern California one of its greatest reputations—beaches. California's development has affected our coastal environment in many ways. Partially treated wastewater discharges have impacted coastal waters by releasing tons of pollutants, such as DDT (a well known, now banned pesticide), suspended solids and many others. The previous Report Card (RC 1998) described wastewater treatment, our successes and failures, and the plans to reach full secondary treatment, which the City of Los Angeles achieved in December, 1998.

But wastewater treatment is only part of the story. Much more contaminated water reaches our beaches and coastal waters through stormwater discharges, or nonpoint sources. This water, usually called stormwater, crosses a variety of land uses, such as yards, roof tops, parking lots and freeways, before it reaches the ocean. Stormwater was previously thought to be clean and not a pollutant. We now know that stormwater, especially from highly developed urban areas, such as parking lots and highways, contains many pollutants that create problems on the beaches and in our coastal waters.

In the Los Angeles area, we average about 15 inches per year of rainfall, which occurs primarily between November and April. Therefore, we have long periods when no rain falls, allowing trash and pollutants to accumulate on land surfaces and in the storm drain system. The first large storm of the season washes a disproportionate amount of trash to the ocean. You may have seen pictures of "trash plumes" extending from major storm drains, such as Ballona Creek, well into the ocean. The first rain of the season, and the first portion of any rainfall, is called a "seasonal first flush" or "first flush." The first flush is always the most contaminated stormwater. Recent work by UCLA investigators, which was also described in RC 1998, has shown that the bulk of the pollutants entering Santa Monica Bay are from stormwaters, as opposed to treated wastewaters. Future efforts to improve the water quality in Santa Monica Bay, and by implication, most other coastal waters in California, must focus on improving stormwater quality. Unfortunately, stormwaters are more difficult to control than wastewaters. They are more dispersed, with a greater number of public agencies responsible for their regulation. It is not yet clear who "owns" stormwater and is responsible for its cleanup.

WHERE STORMWATER COMES FROM

Stormwater flow and quality are a function of many different factors in addition to the amount of rainfall. Hydrologists use a procedure called the "rational method" to estimate the amount and rate of stormwater flow. Historically, the rational method was used to estimate flows in order to design drainage systems to prevent floods. Flood prevention is an important activity of our public agencies, which has generally been performed well. The rational method assumes that the amount of stormwater that flows from a specific area is the product of the rainfall, surface area and a runoff coefficient. The runoff coefficient is related to the imperviousness of the land. Open areas, such as undeveloped land, have low runoff coefficients, indicating that most of the water percolates into the soil, replenishing groundwater sources. Paved areas have the highest runoff coefficient: virtually all the rainfall becomes stormwater.

Highly impervious areas are associated with urban development and failed ecosystems. When imperviousness (percentage of impermeable surface area) exceeds 20 to 30%, the ecology is affected and sometimes destroyed. The increased stormwater volume

Picture 1: Ballona Creek during dry weather. This picture shows Ballona Creek at the Fairfax Street Crossing. The small flow visible at the bottom is dry weather flow.

and flow rate cause streams to undercut their banks, creating erosion problems and destroying habitat for wildlife. Flow rate in streams draining urbanized areas can change from a small trickle to raging torrents in only a few minutes. Erosion problems require flood control agencies to stabilize stream banks, which turns streams and creeks into the concrete channels we see in movies.

Two areas in the Santa Monica Bay Watershed, which UCLA researchers have been studying with U.S. EPA sponsorship are illustrative. The Ballona Creek watershed, draining the west portion of Los Angeles, is highly developed and more than 60% of rainfall becomes stormwater. It is not surprising that Ballona Creek is a concrete channel with water depth that changes from just a few inches before a storm to as much as 20 feet during a large storm (Picture 1). The concrete channel is needed for flood control, but has destroyed the ecology of the creek. Notice the water level in the second picture (Picture 2) of Ballona Creek. Furthermore, the flowing stormwater cuts through downstream wetlands and natural habitats, and deposits silt where there should be none. In contrast, the Malibu Creek watershed is much less developed and only 30% of the rainfall becomes stormwater. Much of this runoff results from the hilly topography, as opposed to its imperviousness, which is less than 30%. Malibu Creek, while affected from urban development, still retains much of its ecology.

The water quality from the two areas is also different. Stormwater from urban areas transports pollutants associated with land uses. Lawns and gardens release nutrients and pesticides, while streets release hydrocarbons, oil and grease and heavy metals associated with motor vehicles. Ballona Creek stormwater is elevated in many pollutants, such as heavy metals (zinc, lead, copper, and nickel). Malibu Creek stormwater, by comparison, is much cleaner. Recent work by the Southern California Coast Water Research Project (SCCWRP), in partial collaboration with UCLA and USC, suggests stormwater from Ballona Creek is toxic to certain aquatic life forms. Heavy metals are the most suspect pollutants. Stormwater from Malibu Creek does not appear to be toxic.

Another problem with storm drains is dry weather flow. Most observers find it strange that storm drains usually have a small flow, even in the driest portion of the year. These small flows result from natural drainage and "nuisance" flows. The flow from excessive irrigation of lawns, leakage, car washing, hosing down of streets and sidewalks, and other small sources, is nuisance flow. There are also permitted discharges into storm drains from cooling towers and, unfortunately, illegal discharges. These flows all add up and become the unsightly trickle across beaches in summer weather. These dry weather flows represent special problems and require innovative solutions.

Picture 2: Ballona Creek during a large storm. This picture shows Ballona Creek at the same location during a large storm. Reference the water level in this picture to the level in the previous picture using the white pipe that crosses the creek. The violence of this storm is evident, and the noise from the flow was so loud that conversation between two people standing at the bridge was not possible. Urban development causes these high flows, which requires the concrete channels to protect property.

WHERE STORMWATER GOES

Stormwater makes its way from the street in front of your house or your roof drains directly to the ocean through a series of pipes, channels, creeks and rivers, which increase in size until they reach the ocean. There are no treatment plants between the stormwater generation point and the ocean. The time of travel in a major storm may be short (generally around five hours from downtown Los Angeles to Santa Monica Bay, via Ballona Creek) or lengthy in dry weather (more than 25 hours during dry weather flow). During the summer, mounds of plants and algae may grow in the concrete channels. Pollutants are often deposited in the stormdrains during low flow. All of this material is flushed out all at once during a large storm. This makes the problems worse, because the beaches are "slugged," and the large slug of pollutants is generally worse than evenly distributed pollutant discharge.

In the Los Angeles area, stormwater flow to Santa Monica Bay is primarily through two large drains, Ballona Creek and Malibu Creek. There are approximately 30 other storm drains that can affect Bay beaches. The Los Angeles River is another major drain, and discharges south of Santa Monica Bay.

The stormwater that reaches the ocean requires time and distance to mix with the saltwater. This occurs because the temperature and density of the stormwater are different from sea water. Observe that the dry weather spill (Picture 3) does not quickly mix with the sea, but meanders in a plume. Eventually, the plume will become fully mixed, but until this occurs, anything in the plume will be exposed to stormwater pollutants, almost without dilution. During wet weather, the volume of stormwater flow at very large drains such as Ballona Creek, is such that the salinity of the ocean near shore can be temporarily reduced.

BEACH CLOSURES

Beach closures are another symptom of stormwater problems. We are routinely told to avoid swimming near storm drains, and not to swim at all after storms (Picture 4). A recent study, partially sponsored and conducted by Heal-the-Bay, suggested that swimmers near storm drains were at greater risk than swimmers far from storm drains. The rapidly flowing stormwater scrubs bacteria and other pollutants from the land to create elevated concentrations on the beaches, and especially near stormdrains. Also, the greatest stress on sanitary sewers occurs during storms. The high water table causes infiltration, which is

Picture 3: Stormdrain showing a spill. This picture shows a spill from a small stormdrain that terminates at the surf. The brown color of the storm water reveals how it flows in a plume and is not immediately diluted. Our public health authorities have posted beaches, telling bathers not to swim close to stormdrains, for good reasons.

leakage of stormwater into sewers. The stormwater may overload the sanitary sewer and cause it to overflow at a downstream location. The overflow is a mixture of stormwater and sewage and contains bacteria and other pollutants, that can cause a serious health risk when it reaches the beach. Stormwater may in rare cases cause erosion problems, which may destroy a sewer or water line, creating a massive spill. The dry weather flow can also create high bacteria concentrations, especially if there is a sewer leak.

Our public agencies are required to monitor coastal water quality to detect leaks as well as assess the impact of stormwater. They use indicator organisms to determine water quality. Indicator organisms are non-harmful organisms that are associated with disease-producing or pathogenic organisms. Indicator organisms are more abundant and easier to measure than pathogens (pathogens are disease-producing organisms). We believe that monitoring indicator organisms is a more reliable way of assessing the safety of beaches than measuring the actual pathogens. Pathogens are more difficult to detect and less abundant, which means routine monitoring may not detect them.

Coliforms are the classic group of indicator organisms and are routinely measured by agencies that monitor beaches as well as those that operate water and wastewater treatment plants. When coliform concentration increases to a specific threshold, a beach is posted or closed. There are different types of coliform tests and new types of indicator organisms are being evaluated. Progress is also being made to more reliably and inexpensively detect pathogens. Rules for beach closures are evolving, and the limits and required responses by regulators vary across California.

A careful examination of beach closure data for the California's coastal counties reveals no significant upward or downward trend in beach closures. There is a definite trend that shows years with greater rainfall result in more closures, but this is expected. On average, less than 4% of "beach miles" are closed. A beach mile is a linear mile of shore line and is an attempt to standardize reporting. Obviously the closure of a single but very large beach is more significant than the closure of a small beach. At first, 4% of the beach miles being closed sounds like a large amount; however, one must realize that beaches adjacent to large stormdrains are always closed. San Diego County has the greatest number of closures but also has the greatest number of beaches. Does this suggest that beaches are getting better or worse?

In spite of the lack of quantitative data, beach water quality is improving. We are monitoring much more frequently than previously. We should expect to find more problems just because of more extensive monitoring. We also know that several long-term problems have been solved. The City of Los Angeles' efforts to upgrade the Hyperion Treatment Plant and replace aging sewers are resulting in far fewer sewage leaks. Other agencies are also making progress. It is now much more likely that a sewer leak will be quickly detected and fixed than 10 years ago.

Efforts are underway at the State Water Resources Control Board to create a statewide database of beach closures and postings. This is partially in response to a new law, AB 411, which requires greater monitoring and posting of beaches when indicator organisms exceed certain thresholds. Additional indicator organism types will also be monitored. The initial results of this law may be counterintuitive. Far more problems will be reported than before, and the stringent requirements will create more beach closures and postings. This will create a perception that beach water quality is worse, when it is actually the same or

Picture 4: Beaches are posted or closed when the indicator organism count exceeds a specific threshold. Beaches that are adjacent to a stormdrain are permanently posted. The public is also urged not to swim immediately after a storm.

improving. The additional monitoring over the next five to ten years will create a much better understanding of beach water quality.

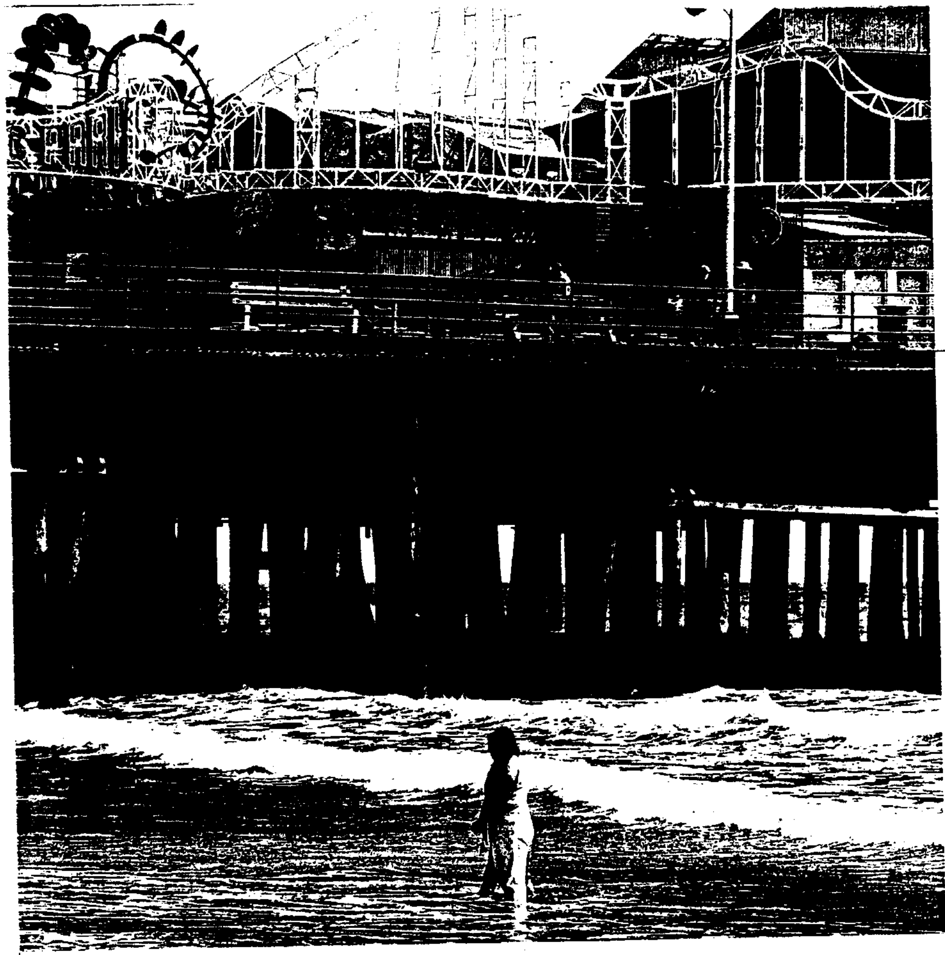
WHAT WE CAN DO ABOUT IT

Stormwater is not as easy to control as wastewater. We cannot simply require an agency to provide treatment. The episodic nature of stormwater precludes the use of treatment plants. One large rainfall, lasting perhaps a few hours, creates more stormwater flow to Santa Monica Bay than our new Hyperion treatment plant can treat in a month. Conventional treatment systems are not appropriate. Instead, we are developing alternative approaches, called Best Management Practices or BMPs. BMPs can be structural, such as stormwater detention basins, or non-structural, such as encouraging the public to practice pollution prevention.

Stormwater pollution prevention must be a joint effort between individuals and public agencies. We also need to rethink some of our building practices. The following section suggests some BMPs for Southern California.

Education: We need to educate the public so they understand that stormdrains are a "large slick pipe" to the ocean. A discarded cup or can will most likely end up on one of our beaches. At present there is no treatment system for stormdrains. Our public agencies have recently instituted stormdrain stenciling to inform the public not to discard trash or pollutants into stormdrains. Litter is infuriating. It is ironic that the same public that wants clean beaches also creates a large part of the problem. Caltrans reports that 20% of the material removed from freeway storm drain inlets is cigarette butts.

Porous Pavement: It is not always necessary to pave areas with 100% impervious material. In other locales, especially in Europe, porous pavements are used. Porous pavement results in more infiltration and less stormwater flow. A variety of forms exist. In some cases, porous pavement can be as simple as using loosely-arranged bricks or concrete blocks. Porous pavements are not applicable to all sites, such as well-traveled freeways. We need demonstration projects to show better the potential applications of this technology.



One large rainfall, perhaps a few hours, creates as much stormwater flow to Santa Monica Bay as our new Hyperion treatment plant treats in a month.

Biomass Injection: If you inspect a parking lot with green space (open space with vegetation), you will probably notice that stormwater is directed towards a drain and not to the green space. Infiltration can occur in the green space and, more importantly, the green space can actually provide treatment for some of the pollutants. Parking lot C at LAX is an example of a site where we should practice biomass injection. The stormwater can be directed to the green space where much of it can percolate into the soil. Excess can flow to a storm drain inlet that is in the middle of the green space. New construction techniques and building codes are required, but they should be no more expensive than existing approaches.

Wetlands, Ponds and Detention Basins: We have little opportunity in our inner city areas to construct wetlands and detention ponds. A wetland is a marsh or swamp (see RC 1998 for more information) in the drain system or coastal area. The natural processes in the wetland can treat many pollutants. Ponds and detention basins are used to capture a portion of the storm flow, especially the first flush. Pollutants can settle out and the stormwater can be gradually released, which avoids scouring pollutants and slugging of the beaches cited previously. These methods are land intensive; however, in developing areas, we can set aside a portion of each new development to provide for stormwater abatement. This is a more common practice on the East Coast.

Trash Screens and Racks: Recent approaches to screening stormwater to remove trash and debris are being evaluated in several places in Southern California. These new technologies may be able to remove trash and gross solids without excessive maintenance or flood control risks. The solutions are not cheap, but will probably provide a viable alternative for trash control. Figure 1 (p. 19, top) shows how these screens work.

Low Flow Diversion: It is possible to pump the dry weather flow from stormdrains to sanitary sewers. This BMP was suggested by the Pico-Kenter Stormdrain task force in the early 1980s. In dry weather, the small flow in the stormdrain is pumped to a sanitary sewer. It flows to the treatment plant and is eventually discharged through ocean outfalls. New treatment plants such as Hyperion have the capacity to handle these flows; furthermore,

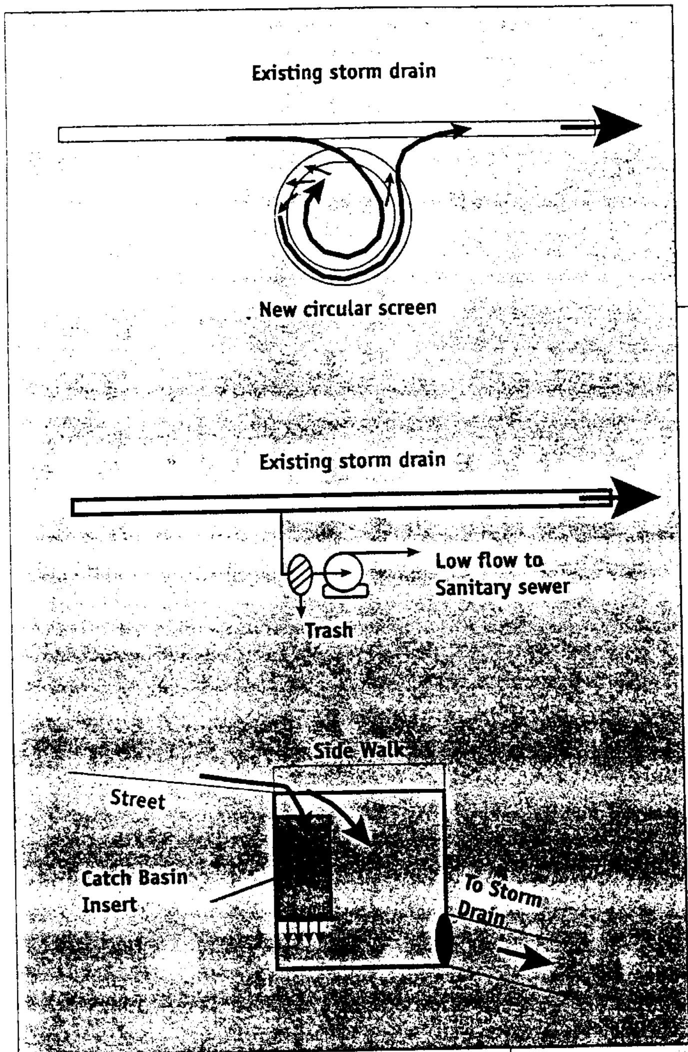


Figure 1

This figure shows three alternative Best Management Practices for stormwater. All have been investigated or proposed by researchers at UCLA.

The top of this figure shows a new type of screen being installed at several places with Proposition A funding. The screen is constructed next to an existing storm drain, represented by the two horizontal lines. A small diversion (weir) is placed in the storm drain to direct a fraction of the flow through the screen. The specially designed screen resists clogging and capture trash, debris and large solids. The captured material must be removed periodically and disposed to a landfill or other appropriate place. These devices are designed to treat the first flush and the smaller storms. Very large storms will bypass the screen.

The middle diagram shows a diversion for low flow. This low flow trickles across our beaches to reach the ocean. By installing a diversion, the low flow can be pumped to a sanitary sewer, then to a treatment plant, such as the Hyperion Plant, where it is treated and discharged several miles away from the cost.

The bottom figure shows a catch basin insert. Normally stormwater flows across the street to an opening in the curb, and from there into a small storm drain that eventually flows to a large drain such as Ballona Creek. Solids, trash and debris collect in the basin. One goal is to clean the basins before the wet season, which prevents the dry weather accumulation (trash, debris, road dust and particles) from reaching the ocean. During wet weather, small storms wash material into the catch basin which accumulates until it is flushed out in a large storm. The insert shown in the figure is a method of trapping the accumulated material so that it is retained in the basin. More advanced inserts have sorbents that will remove a large portion of the suspended solids and oil and grease. The inserts must also be periodically cleaned and replaced.

For over 90 years Civil Engineers have been separating stormwater from the sanitary sewer. Now we are telling them to put the low-flow stormwater back into the sewer.

dry weather flows occur when there is no infiltration (ground water that seeps into sanitary sewers), which reduces load on the treatment plant. The City and County of Los Angeles are planning several such diversions, and ten are in some state of planning or completion at present. Figure 1 (p. 19, middle) shows a diversion.

Street Sweeping and Catch Basin Cleaning: Street sweeping prevents trash and gross pollutants from entering stormdrains. Better sweeping methods to increase the recovery of small particles are being developed. Catch basins (the opening on the street where stormwater enters the stormdrain) can be more aggressively cleaned and maintained. Recent research conducted at UCLA and partially sponsored by a consortium of cities, lead by the City of Santa Monica, has demonstrated that catch basin inserts can retain pollutants and avoid flooding problems. Figure 1 (p. 19, bottom) shows an insert.

Product Replacement and Pollution Prevention: We now know that certain products are more polluting than others. Automobile brake pads are an example. Some brake pads have high metal content, which becomes a stormwater pollutant as the pads wear. Work is underway to provide brake pads with less metal content. There are numerous other examples. Many industries and businesses can practice pollution prevention. Simple measures, such as providing covered storage for product inventory, can significantly reduce stormwater pollution. The public needs to understand and practice pollution prevention techniques. Vehicle inspection programs to reduce smog also reduce stormwater pollution.

WHAT HAVE WE DONE?

How well are we doing? Unlike last year's report on wastewater treatment, the answer is not so clear. Stormwater management is a much more difficult problem than wastewater management. The reasons are both technical and institutional. Although stormwater management was required by the 1972 Amendments to the Clean Water Act, we are still struggling to create a regulatory framework. Successful stormwater management must be practiced by individuals as well as agencies.

The Santa Monica Bay Restoration Project has funded several significant studies to better understand stormwater and mitigate its impacts. This research is continuing, but there is still a long way to go. At least we can now estimate the mass of pollutants from stormwater and treated wastewater; five years ago we could not even do this.

Proposition A is funding a number of construction projects to demonstrate stormwater management approaches. These include screens and trash racks, catch basin inserts, low flow diversions and other management strategies. The successful projects will become models for long-term, full-scale projects and long term changes.

Monitoring programs are improving. The Los Angeles County Department of Public Works is creating a monitoring program, which should eventually be able to measure stormwater runoff from the entire County. Increased beach monitoring will also assist in isolating problems and encouraging solutions.

The rededication to wastewater treatment has resulted in new treatment plants and new sewers. We now have the capacity for low flow diversion in the City of Los Angeles' Hyperion Plant. Preventing sewage spills should have the highest priority. The technology exists to greatly reduce sewage spills.

The past record is not all good. In some instances our public agencies acted only after being sued by environmental advocacy

We previously thought stormwater was clean. Now we know that stormwater transports more pollutants to Santa Monica Bay than the treated wastewaters.

groups. Caltrans, which initially resisted efforts to clean freeway stormdrains, now has an aggressive program to develop solutions preventing freeway stormwater pollution. The U.S. EPA and the Regional Water Quality Control Board are now dedicated to developing a total management daily load (TMDL) for litter from stormwater. Other TMDLs will also be developed.

SUMMARY AND THE GRADE

Large challenges still exist. We lag behind many East Coast and Pacific Northwest communities in preventing stormwater pollution. We are better than many rapidly growing cities, particularly in Asia, where stormwater pollution is sometimes out of control. Unfortunately many of the challenges are not technical, but institutional, and therefore usually more difficult to address. We need to change building codes to improve stormwater management. In many cases, this will result in less development, and we must require developers to set aside land and resources for stormwater management. Agencies responsible for flood control must now understand that pollution control is an equal part of their mission. They must be proactive in developing alternatives that reduce stormwater pollution while providing flood protection. We must reconsider the assumption that the public is not willing to pay for environmental protection. There is ample evidence, especially in the Southern California region, that the public is willing to pay for protection, provided they understand the reasons and are assured the measures are economically and fairly applied. Our regulatory agencies do not have the staff to fully implement the required programs. Clearly, all individuals must practice stormwater pollution prevention in their everyday actions; the blunt truth is that one of our largest problems, litter, could be solved at no cost if people just behaved differently.

Our compromise grade is B. We have not protected the environment sufficiently to earn a B, but the problems are so challenging that we collectively deserve a B for our efforts.

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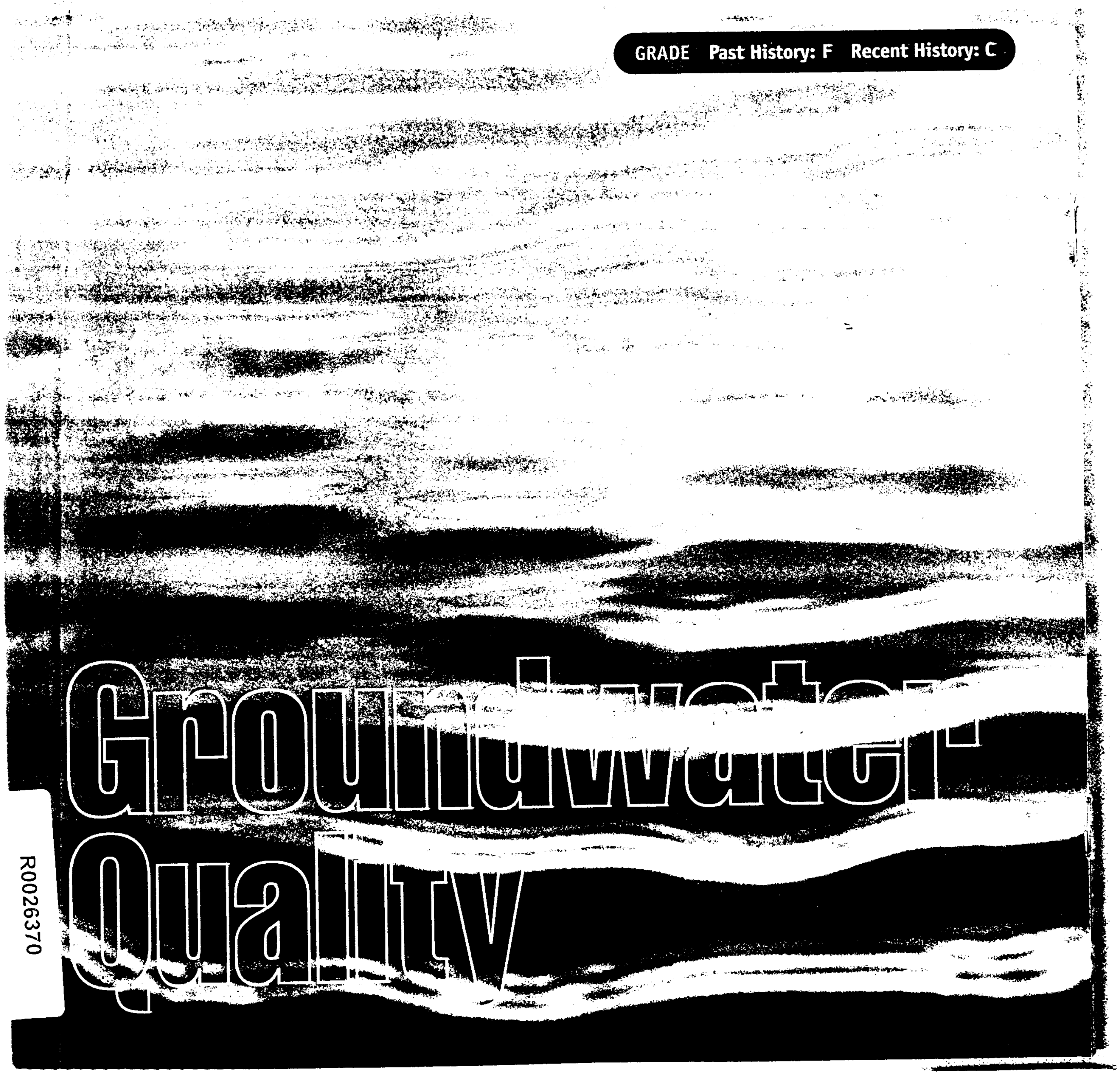
Professor Stenstrom received his Ph.D. from Clemson University in 1976 and worked two years in industry before joining UCLA in 1977. He currently serves as chair of the Civil and Environmental Engineering Department. He has written more than 150 scientific publications and received more than $10 million in grants and contracts. He also serves as a consultant to municipalities and industries that wish to improve their treatment systems.

GRADE **Past History: F** **Recent History: C**



Groundwater Quality

by Tom Harmon, Ph.D.

Professor, Department of Civil and Environmental Engineering

INTRODUCTION

Southern California depends on subterranean water, or groundwater, to supplement its water supply, yet this valuable resource is often overlooked by the general public as an environmental issue. In Southern California, groundwater problems tend to be overshadowed by the more readily observable problems of air or water pollution. This attitude toward groundwater is probably more a case of 'out of sight, out of mind' than one of outright neglect. Nonetheless, ignorance concerning this resource has garnered a woeful legacy of groundwater contamination that will require decades of effort and billions of dollars to mitigate. Thus, it is timely to consider the historical demise of our groundwater resources and what we want to do about these resources in the future.

As Southern California's population and economy grew during the latter half of this century, so did the scope of its groundwater quality problems. Many new and useful chemicals were produced, including 'chlorinated solvents', such as trichloroethene (TCE) and perchloroethene (PCE), degreasing agents used in vast quantities wherever mechanical or electronic components needed cleaning. With their use came leaking tanks, spilling buckets and hasty, poorly monitored disposal of spent solvents. Such behavior appears negligent in hindsight, but was, in most cases, simply the standard practice at the time. This is not surprising for it was a remarkable era of growth for Southern California, and there was little time for environmental foresight.

The purpose of this article is to promote an understanding of groundwater quality as a topic of environmental concern, and to define relevant technical and legislative issues associated with groundwater and its degradation as a resource. Perhaps the most important point to be made is that groundwater quality problems develop over a long time, and require an even longer time for clean up. We illustrate this point by way of a historical narrative about the San Fernando Valley groundwater basin. Finally, the discussion turns to the state of this resource in Southern California today, and its future outlook.

HYDROGEOLOGY 101

Hydrogeology is the study of water quantity and flows in the subsurface terrain (see Figure 1). Groundwater is a generic term for water that has accumulated in appreciable quantities in the pore space of unconsolidated or loose sediments, or in the fractures associated with bedrock. This subsurface reservoir serves as the dominant source of fresh water in the hydrologic cycle. Indeed, groundwater comprises about two-thirds of the fresh water supply on this planet. This water percolates into the ground, a process referred to as groundwater recharge, mainly during the rainy season. It can exit the subsurface through the roots of plants, the beds of rivers, lakes and streams, or water production wells.

Like water in rivers or in pipes, groundwater flows from zones of higher elevation or pressure to zones located downhill, or at lower pressure. Under special circumstances, groundwater pressure differences develop vertically, giving rise to the upwelling of natural springs. However, groundwater flow is typically horizontal and slow, its progress constantly impeded by the surrounding filter material (the soil). In fact, a groundwater velocity of 100 feet per year is considered normal. A slow flow rate means the residence time, or the average time spent by a parcel of water in a groundwater system, may be years, decades or even longer.

Contaminant hydrogeology is the study of the fate and transport of chemicals in groundwater. We have a reasonable understanding of how chemicals pollute groundwa-

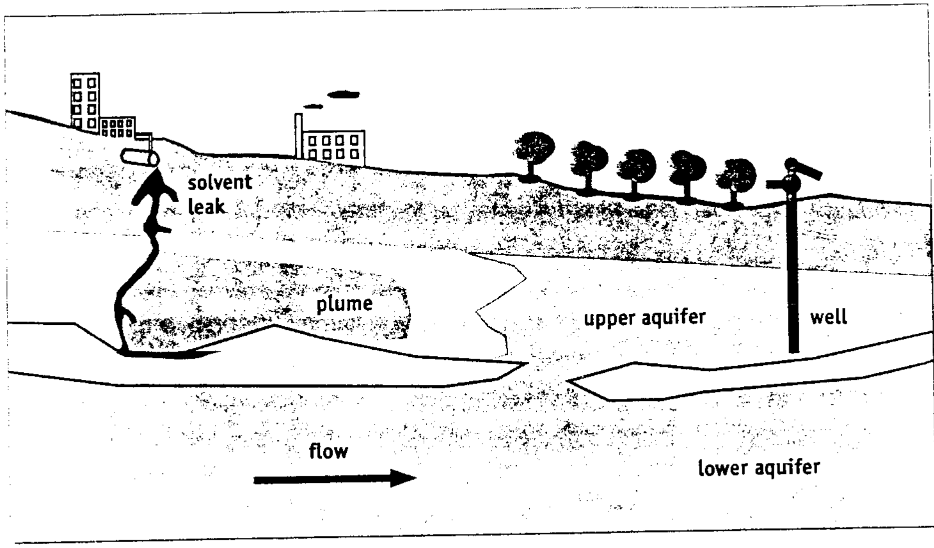


Figure 1: A schematic diagram of a subsurface environment where dissolving solvents are tainting the groundwater supply.

ter once they have been released into the subsurface. They first percolate through the soil until they reach the groundwater. There, they begin to dissolve very slowly into the passing flow, creating expansive plumes of tainted groundwater. The PCE plume shown in Figure 2 depicts this process in a carefully controlled laboratory setting. The slow bleeding characteristic of this chemical dissolution process is due mainly to the sparingly soluble nature of the chemical. PCE, for example, is soluble in the amount of about 150 milligrams per liter of water, or 150 parts PCE per billion parts water.

Regardless of its low solubility, PCE is legally regulated at an even lower level of just five parts PCE per billion parts water. This extremely low limit is due to adverse health effects thought to be associated with long-term exposure to this chemical. The definition of 'long-term exposure' gets fuzzy, but can be interpreted to mean regular drinking and bathing by a community will result in an increase in certain types of cancer and birth defects. Thus, even small spills of these chlorinated solvents can inflict enormous damage upon groundwater basins.

AN HISTORICAL PERSPECTIVE: THE SAN FERNANDO VALLEY

There are Southern Californians alive today who remember when Los Angeles was little more than a bustling town surrounded by picturesque rural scenery. As late as the 1960s, vast portions of the San Fernando Valley remained as part of that scenery. However, the post-war industrial boom and associated influx of population have drastically altered that picture of the Valley, and with it the underlying groundwater resources of the Valley.

To better understand the history of the San Fernando Valley with respect to groundwater, a brief mention of the underlying hydrogeology is in order. Figure 3 depicts a map of the San Fernando Valley floor nestled within the confines of the surrounding mountains. Large zones beneath the Valley floor are known as alluvial aquifers, water-bearing layers of sand and gravel deposited over thousands of years of erosion and deposition of the surrounding mountains. Regional groundwater generally follows the path of the Los Angeles River, flowing from west to east across the valley, then funneling south through the LA River Narrows. In the wider, western expanses of the basin, groundwater flow rates are as slow as 5 feet per year. At the Narrows, flow velocities on the order of 1300 feet per year have been estimated.

There are three key water-bearing zones in the basin which we can refer to as the recent or upper alluvium, the older or lower alluvium, and the Saugas formation, or deep zone. The upper alluvium extends from the

Even small spills of these chlorinated solvents can inflict enormous damage upon groundwater basins.

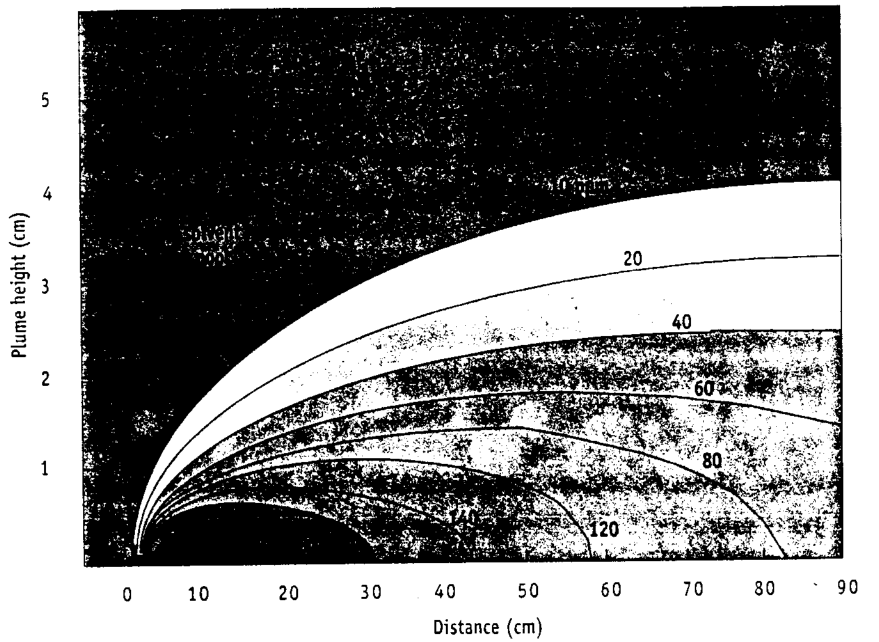


Figure 2: Contaminated groundwater pattern emanating from a dissolving solvent pool as observed by Dela Barre (1999)

ground surface to depths of roughly 200-250 feet. This zone is not fully saturated and the water levels there are quite sensitive to recharge and water usage. The lower alluvium extends to depths of 400-600 feet, and is separated from the upper zone by a layer of about 50 feet of finer sediments. This layer serves as barrier protecting the lower zone from water quality problems in the upper zone. However, the barrier is not failsafe because its thickness and the fineness of its sediments vary widely throughout the basin. Beneath the lower alluvium is the deep zone, which, due to its depths, has been the least-explored of the basin aquifers. It extends to at least 1,200 feet below the ground surface. Historically, groundwater extraction from the basin has been from the upper and lower alluvial zones.

The historical records for water levels in two San Fernando Valley production wells (Figure 4) provides an effective time-line for groundwater usage in that basin. Well 3700A is located in the southwest part of the basin, near Reseda, while Well 3914H is at the eastern end, near Glendale. For both wells, the record indicates consistently high water levels into the late 1940s followed by a steady decline. A severe drought during the late 1940s and early 1950s was responsible for the initial decline in water levels. However, drought alone cannot explain that the water levels for both wells continued to be depressed until the 1970s. Instead, these lower levels must be attributed to the increasing demands placed on groundwater in the basin over this period.

From the late 1970s forward, there was a rather rapid recovery in Well 3914H to pre-1940 levels, yet for the more westerly-situated Well 3700A, there was no such recovery. This difference is representative of the rapidly changing groundwater usage patterns in the San Fernando Basin during this period. Orchards had given way to the housing tracts needed for the growing army of factory workers of the post-war industrial boom. More significantly, this period of highly variable groundwater usage also serves to signal the beginning of historical groundwater quality problems in the San Fernando Basin.

In 1980, traces of industrial solvents, especially TCE and PCE, were detected in San Fernando Valley production wells. This discovery led to drastic reductions in

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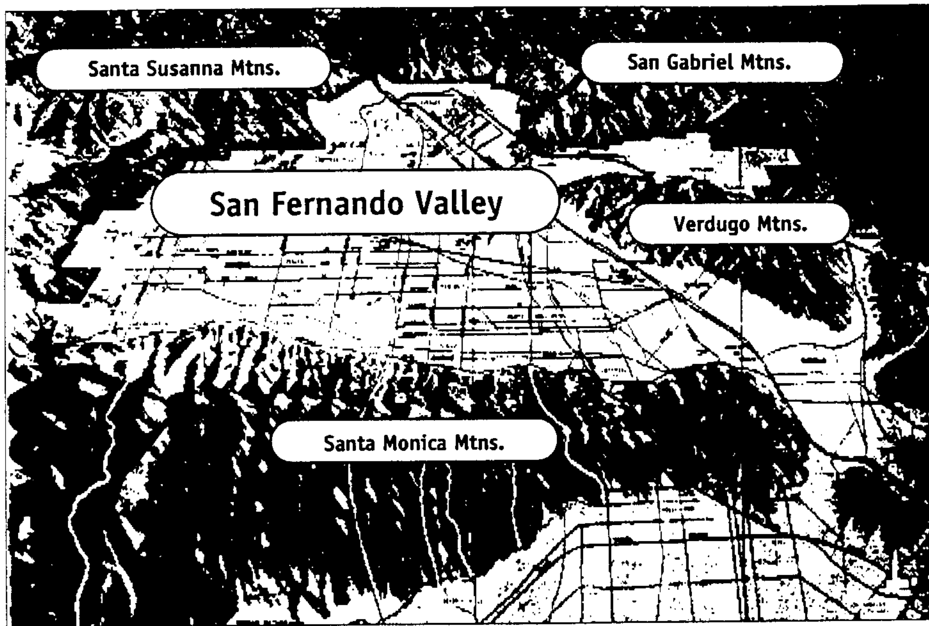


Figure 3: An overview of the San Fernando Valley and surrounding mountains.

groundwater extraction, particularly in the highly industrialized eastern end of the basin. As the 1980s progressed, it became apparent that the soils underlying many prominent factories of the Valley were affected by spills and leaks of these compounds and other toxic chemicals. Ironically, it may have been the reduced pumping of the late 1970s that first brought the groundwater in contact with many of these spills. In 1987, the U.S. Environmental Protection Agency (U.S. EPA) initiated a five-year remedial investigation of the groundwater contamination in the basin. The soils and groundwater underlying the streets and towns of the San Fernando Valley had become a gigantic Superfund site.

The plot in Figure 5 depicts the estimated extent of the upper aquifer TCE plume in the San Fernando Valley in the Spring of 1996. The creeping plume remains largely unchanged today. It is roughly 17 miles long and may contain more than 200 trillion gallons of contaminated groundwater. An interim strategy for extracting and cleaning groundwater at the front of the plume has been designed and will be implemented over the next 12 years while the responsibility and liability of various parties is assessed. However, the ultimate time-frame for cleanup is three decades or longer.

Unfortunately, the San Fernando Valley is not unique. The other major valleys, the San Bernardino and San Gabriel are also Superfund sites with problems very similar in size and scope to those associated with the San Fernando basin. Numerous landfills and military bases offer still other examples of Southern California's hazardous waste legacies in groundwater (see sidebar page 30).

OTHER CURRENT GROUNDWATER QUALITY ISSUES

Due to their ubiquitous usage and stability or staying power in the environment, chlorinated solvents such as those discussed above are the leading source of groundwater contamination in Southern California and the rest of the United States. However, there are many other groundwater contamination issues in our region, such as those associated with fuels, agricultural wastes, septic systems and sea water intrusion.

In the 1980s, it became clear most of the underground storage tanks at gas stations were leaking gasoline into groundwater. Of particular concern in gasoline leaks is benzene, a known carcinogen that is very mobile when released into the environment. As any Los Angeles motorist would suspect, repairing the tank systems and restoring the soil and groundwater around most corner gas sta-

The record for cleaning up contaminated groundwater in Southern California is not very strong.

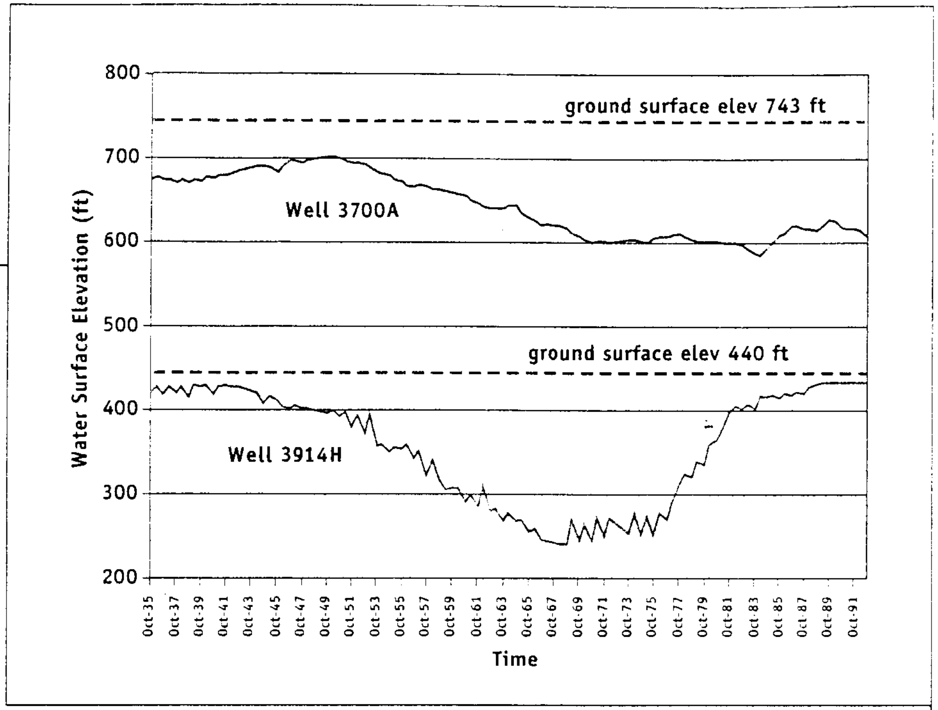


Figure 4: Historical depths to water for two San Fernando Valley drinking water wells (ULARA Watermaster Report, 1995)

tions in the region is an expensive proposition to say the least. Indeed, an estimated $2 billion dollars has been spent on this task in California throughout the early 1990s.

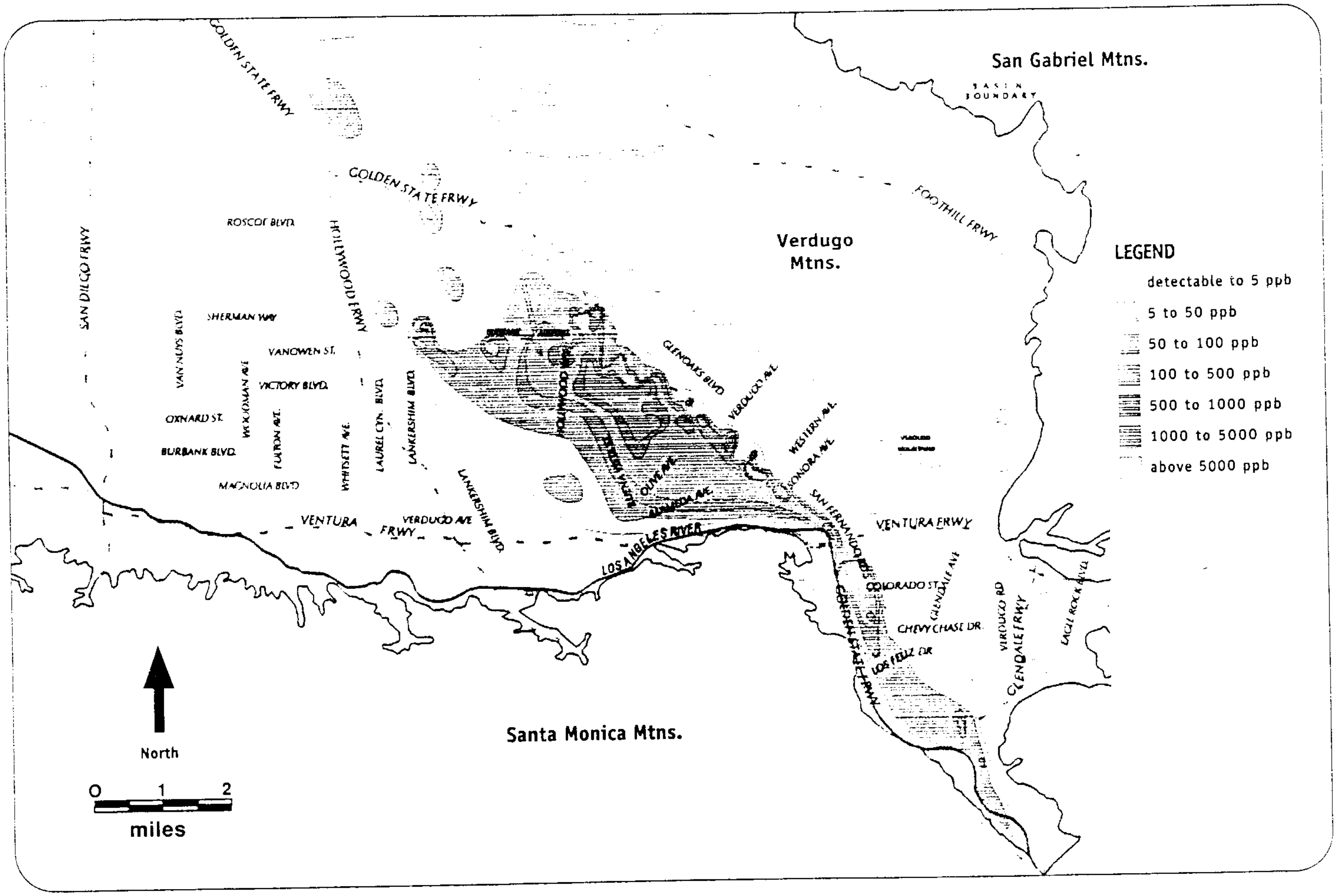
In the face of these costs, a movement toward more economically feasible strategies based on risk assessment was begun. A study regarding gasoline releases in the subsurface was commissioned by the state in 1995 and carried out by an advisory committee composed of scientists from several University of California campuses. The committee reported the human health risk associated with such gasoline releases was relatively small. They noted that plume reduction was generally already underway at such sites due to the biodegradability of gasoline components. Just as momentum was beginning to build behind the notion of worrying less about leaking underground gasoline tanks, a new problem arose in the form of cleaner burning gasoline mixtures.

Around the late 1980s, reformulated gasoline mixtures were introduced to help alleviate air quality problems associated with automobile emissions. A key ingredient in these mixtures was methyl tertiary-butyl ether (MTBE). Despite recent efforts to correct the problem of leaking underground storage tanks, MTBE has made its presence known in Southern California groundwater supplies, suggesting that even new tanks are leaking. In the city of Santa Monica, drinking water production wells in the Arcadia and Charnock well fields have been closed due to gross MTBE contamination. Based on its chemical properties and ubiquitous presence in California groundwater, MTBE is even more mobile than benzene, the previous gasoline component of interest. Based on a State-commissioned UC-wide study on MTBE in 1998, Governor Gray Davis proclaimed in March 1999, California will phase out MTBE over the next five years. Clearly, the full environmental impact of this chemical was not adequately assessed before it was introduced into our gasoline supplies.

HOW WELL ARE WE DOING?

Unfortunately, the record for cleaning up contaminated groundwater in Southern California is not very strong. There are many reasons for this poor progress. First, it can take years to gather sufficient information, through exploratory drilling and well sampling, to begin engineering proper cleanup strategies. Second, hazardous chemicals have had

Figure 5: Plume map showing the estimated extent of dissolved trichloroethylene (TCE) propagation in the San Fernando Valley's upper aquifer (adapted from U.S. EPA database)



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Groundwater quality problems are often a case of out of sight, out of mind.

decades to spread out in the subsurface. Given that federally mandated cleanup goals for many of these chemicals (MCLs) are extremely low, cleanup of major groundwater quality problems, even under the best of circumstances, is a decades long proposition.

In addition to these technical reasons, cost issues are prominent in our failure to complete the cleanup of our groundwater resources. One unsavory problem is that many of the responsible parties view cleanup as a long-term and expensive penalty for what they consider to have been standard operating procedures of a bygone era. As a business they prefer to pay to contest their problems in court rather than expend resources on the cleanup. While litigation costs may be substantial, they are dwarfed by long-term cleanup measures. Furthermore, if a case is stalled long enough, there is always a chance a responsible party's problem will disappear, either by natural dilution processes or through changes in our laws.

On a more positive note, groundwater-related legislation appears to be doing a good job of at least controlling present waste disposal practices. Federal and state agencies, like the Environmental Protection Agency (U.S. EPA), Cal EPA and Regional Water Quality Control Boards are generally aware of most hazardous waste problems with groundwater repercussions. This is not to say there are no longer any active hazardous waste landfills: there are many. These agencies now operate a system of checkpoints to help minimize, supervise and track the waste. And, as the final defense before our taps, Southern California drinking water agencies are also aware of potential problems and regularly screen drinking water for hazardous contaminants. Most of these chemicals are easily removable once identified.

THE FUTURE

Despite this apparent progress, there is still substantial room for improvement in all of these areas. If the recently installed checkpoints discussed above prevent the occurrence of new hazardous waste sites, then they will have served a purpose. However, as we noted at the outset of this article, groundwater quality problems are often a case of 'out of sight, out of mind'. This is also true when it comes to budgets, where funding for local, state and federal agencies, as well as that for education and research, has a tendency to disappear in favor of more visible problems. As a society we need to lobby local, state and federal officials to keep groundwater restoration and preservation in mind when making decisions affecting land and water usage. Some difficult decisions about our groundwater resources will be made in the not-so-distant future. First and foremost, we will need to decide whether we want to pay to clean our aquifers to the levels currently dictated by the law. Those in favor of the cleanup might point out it is a dangerous precedent to begin relaxing environmental standards for any resources. The major impediment to this alternative is it will force us to share the cleanup costs, both as conscientious citizens and as consumers of the products causing the

A glimpse of groundwater seeping from exposed fractures in cliffs along the Southern California coast.

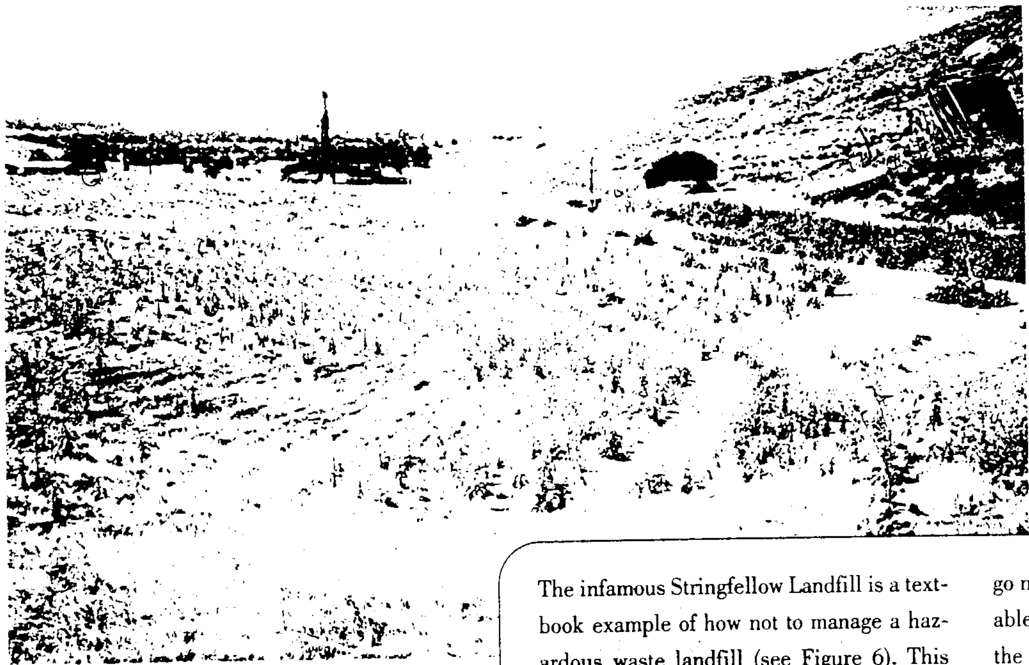
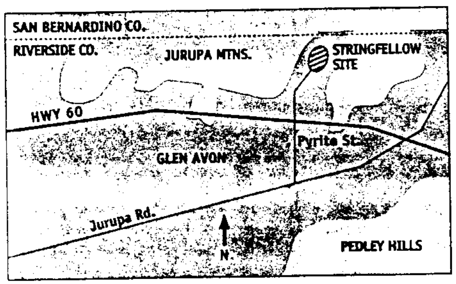


Figure 6: A recent view of the infamous Stringfellow Landfill site as it undergoes remediation.



The infamous Stringfellow Landfill is a textbook example of how not to manage a hazardous waste landfill (see Figure 6). This remote, horseshoe-shaped canyon was designated as a potential hazardous waste receptacle by the State of California on little more than a 'drive-by' inspection in 1954. Under extreme pressure from the booming post-war chemical industry, the State lost no time in permitting landowner and quarryman, J.B. Stringfellow Sr., to operate the landfill. With little or no authoritative supervision, the site received an estimated 32 million gallons of hazardous waste between 1956 and its closure in 1972. At its peak operation, waste was dumped into the site's so-called evaporation ponds 24 hours a day. It was believed at the time that the hot, dry conditions would disperse the chemicals into the atmosphere at a rate greater than they were being delivered. It was also believed that any waste that did infiltrate into the subsurface would go no further than the underlying impermeable bedrock. To compound the problem, the waste was often dumped without regard to segregation of incompatible chemicals. The record is rife with horror stories of these ponds catching fire or erupting with toxic clouds. And beneath the surface more enduring problems developed as chemicals seeped through the pond bottoms and underlying sediments into the groundwater below. In hindsight, the reason for this seepage is clear: the bedrock contained a network of fractures which served as efficient conduits for conveying the toxic waste. The photograph in Figure 6 shows the site as it stood in 1992, after nearly 10 years of subsurface investigation and remediation design. Groundwater extraction and treatment, at an on-site treatment plant continues today. It is estimated that nearly half a billion dollars will have been spent on the site before work there is completed.

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It is a dangerous precedent to start relaxing environmental standards for any resource.

pollution. Those against cleanup might just as rightfully argue that any water marked for consumption is easily treated on an 'as-needed' basis. One impediment to this alternative is the negative public perception regarding drinking water that was formerly referred to as wastewater. If and when this impediment is overcome, we will again need to be prepared to share the cost. In this case, the cost will be associated with the more advanced water testing and treatment processes that such a policy will require.

GRADES

The grades on our protection and restoration of groundwater resources are presented on a historical basis:

Past History: F. The extent of the damage that was done from the 1940s through the 1970s was enormous. There were no watchdog agencies to protect the public interest. The only positive note is that, in most cases, we really did not know what we were doing. We can liken this grade to the one you would expect to receive when you find that you have been going to the wrong classroom for three weeks. Then, when you finally arrive at the right classroom, it's the day for the midterm exam.

Recent History: C. Despite the fact we now have the agencies and technology to address many of our groundwater problems, we remain satisfied with keeping the problems from getting worse. In part, this attitude has been brought about by the nature of subsurface problems, which are difficult and expensive both to characterize and solve. However, a large portion of this attitude is part of a pervading mood of ambivalence regarding what really needs to be considered when it comes to cleaning up groundwater: responsibility, risk, cost, time, or some as yet unknown combination of these factors.

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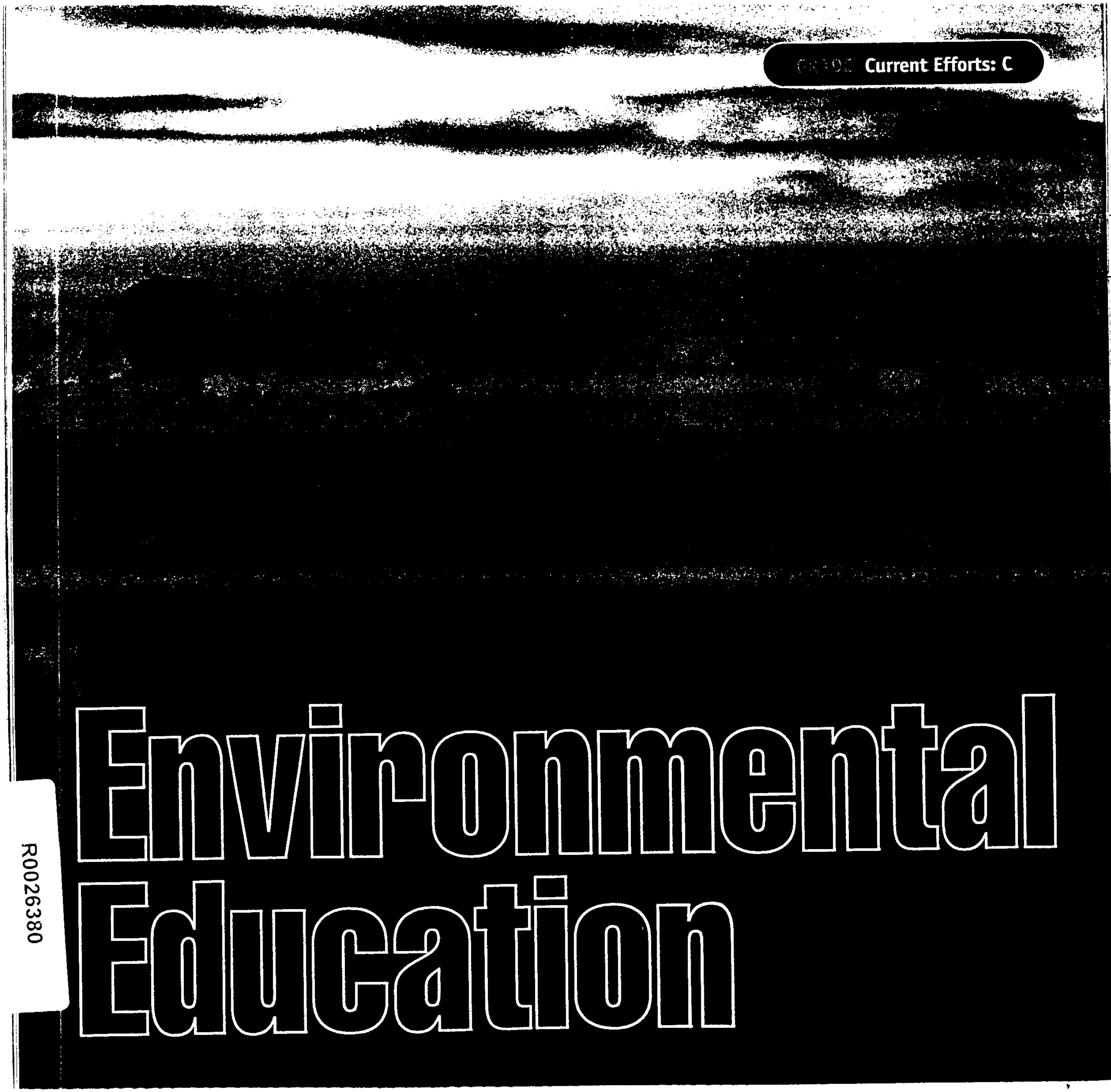
Thomas C. Harmon is an associate professor in UCLA's Civil and Environmental Engineering Department. His research focuses on trying to understand the movement and fate of contaminants in soils and groundwater, and engineering effective physical, chemical and biological technologies for addressing this problem. His current work involves basic topics related to the behavior of chemicals in soils, and more applied topics related to tracking and mapping contaminant spills in subterranean space and restoring urban brownfields to productive use. As an instructor, he is committed to infusing the latest technology into the curriculum, and is currently developing virtual reality-base instructional software to help accelerate this process.

Professor Harmon received his B.S. in Civil Engineering from Johns Hopkins University in 1985. He received his Ph.D. from Stanford University in 1992, at which time he joined the faculty of UCLA. In 1995, he was awarded the National Science Foundation's Early Faculty Career Development Award.



Current Efforts: C

Environmental Education

by Janet M. Thornber, MSPH

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UCLA Graduate School of Education and Information Studies

WHAT IS ENVIRONMENTAL EDUCATION (EE)?

If we assume that education leads to literacy then the first question we should ask is "What is environmental literacy?" Earlier this decade, the Environmental Literacy (EL) Framework described environmental literacy as multi-faceted, including a cognitive dimension (knowledge and skill); affective dimension (attitude); and a behavioral dimension (individual or group involvement in environmental action). In 1992, C. Roth defined EL as "essentially the capacity to perceive and interpret the relative health of environmental systems and take the appropriate action to maintain, restore, or improve the health of those systems."

TOWARD ENVIRONMENTAL LITERACY FOR ALL

Should all our students become environmentally literate? A quick answer is "yes." Today's students, both from disadvantaged and non-disadvantaged groups, have listed many concerns, with their environment being high on the list. Students need opportunities to learn they are part of their environment—not observers of it, that it belongs to them as much as to anyone else; and that they, too, can understand it and have a role in its stewardship. In addition, many environmental advances have been made over the past two decades—Los Angeles' air is cleaner now than in the '70s (see RC 1998), and we must ensure that future generations maintain this progress. Students need not become ardent environmental activists nor research scientists, but literate voting citizens who can make decisions based on sound knowledge and evidence—even though some of these decisions may not be in tune with the local environmentalists' perspectives.

Environmental agencies and organizations (including the California Department of Education) that responded to a 1995 survey leading to the report *Pieces of a Puzzle: An Overview of the Status of Environmental Education in the United States* support EE for all:

- "Each individual should have a basic understanding of the environmental sciences"
- "Each individual should understand the relationships between human actions and the environment"
- "Environmental education should be integrated into all school curriculums"
- "Diverse environmental education opportunities should be available to the general public"
- "Environmental education in the state should be a cooperative venture, coordinated at all levels within the state and with national and international networks."

ENVIRONMENTAL RESOURCES

How can we, as educators, help students achieve environmental literacy? Over the past 10-15 years, diverse curricula projects have been developed from a variety of funding sources, each with their own agenda. For example, money from the California License Plate Fund has developed *Project WILD* and *Project Aquatic WILD*. These popular curricula provide classroom activities that model environmental concepts such as population fluctuations, impacts of toxins on food chains and webs, and the effect of the destruction of habitats on local species. Although designed for K-12 grades, they are most popular with elementary teachers. The California Department of Education (CDE) has supported the development of *A Child's Place in the Environment*, a K-6 curriculum that considers a specific environmental concept at each grade level. The Lawrence Hall of Science has

Teachers explore the ecology of Mono Lake.

developed environmental programs such as SEPUP (Science Education for Public Understanding Project) among their many programs for K-12 students. UC Santa Cruz has developed *Life Lab*, a program that uses school gardens as a vehicle for teaching science.

Local and state utility companies also provide a rich source of environmental education materials. The Los Angeles Department of Water and Power (LADWP) had a far-reaching education program until funding was reduced recently. Fortunately, many publications remain that promote understanding of water issues in the city, including transport to the city, purification, and delivery to customers. The Metropolitan Water District (MWD) had corresponding materials. Waste disposal concepts can be taught through *Closing the Loop*, a curriculum developed by the Los Angeles County Department of Integrated Waste Management, in which landfills provide the vehicle for teaching science concepts. Other programs include *Earth Resources*, a program developed by a consortium of oil companies in Texas. These latter two programs are geared toward teachers of secondary grades.

As well as published environmental education curricula, local school districts provide environmental instructional experiences for their teachers and students. For example, the Los Angeles Unified School District (LAUSD) works closely with the Los Angeles County Office of Education (LACOE) to take students to outdoor camps during the academic year. LACOE and LAUSD also offer the Yosemite Institute and Eastern Sierra program for teachers and students. In addition, there are marine science programs offered through Sea Education Afloat and the Roundhouse Marine Science Laboratory in Manhattan Beach. UCLA has developed a small aquarium, the Ocean Discovery Center in Santa Monica, and a marine science program at Fort McArthur that provide programs for students and teachers.

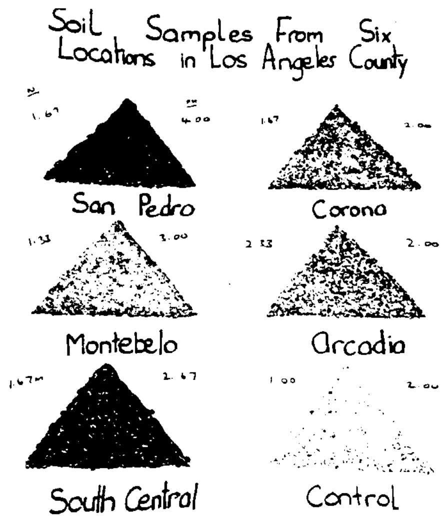
Care must be taken by teachers as they use environmental curricula, especially those published by strong activist groups that obviously further their own specific causes. It is easy to get caught up emotionally in these causes. Environmental issues are not black and white; there are many perspectives from which to study them. Teachers must remain even-handed whatever their own personal views. This does not mean that students should be shielded from activists. But they should be given opportunities to see issues from the perspectives of all stakeholders such as land developers, city councils, local water authorities, tax payers and others. One of the best teaching strategies is the classroom debate. Students must defend the perspectives of interested parties (such as those listed above), thus enabling them to see issues from all perspectives—an uncomfortable but illuminating exercise.

In addition, although it may not be the role of EE to develop activists, it is certainly the role of EE to help students learn actions they can take in their own personal lives that will support a healthier environment. They can learn how to conserve resources such as power and water, recycle, and dispose of toxic materials properly. Action must, of course, be linked to science and social science principles.

ENVIRONMENTAL EDUCATION IN SOUTHERN CALIFORNIA

Visits to local secondary school classes provide varying pictures. In some cases, you will see secondary and elementary students out on field trips to local areas such as the wetlands,

Children in elementary grades respond well to lessons on their environment. Such lessons provide concrete experiences upon which they can build more sophisticated understandings.



Tujunga Wash, the Los Angeles River, and Castaic Dam, learning to understand environmental issues first hand. Others may be reading about them from newspaper or Sierra club articles and debating issues as a means to seeing all sides of specific concerns. Others may never get to environmental science because it's usually the last chapter in the text.

At the elementary level, the approach to EE is somewhat different. Most published programs referred to earlier offer workshops to teachers to help them become familiar with the curriculum, the environmental issues addressed, and, to a greater or lesser extent, the science behind them. However, the report *Pieces of a Puzzle* finds the average length of an EE teacher training program is 2-4 days. Hence the depth of content and quality of teacher training is severely limited. Although follow-up is usually provided in the form of newsletters, Internet sites and telephone hotlines, the preferred method— providing mentor teachers as support—is not common.

University faculty and teachers (usually those of secondary grades) question whether one should introduce students to basic science concepts first and then relate them to the environment, or introduce students to environmental issues and then help them understand the science behind them. There seems to be no hard data on what works best. But, from observations of instructional practice, it is easy to see that environmental curricula are popular with elementary students and teachers for several reasons. Children in elementary grades respond well to lessons on their environment. Such lessons provide concrete experiences upon which they can build more sophisticated understandings. Many teachers, including those less-well prepared to teach science, feel more comfortable teaching science through environmental topics. They often feel more comfortable taking their students outside to explore and ask questions than setting up explorative activities in their classrooms. In addition, elementary teachers relate environmental lessons to those in social studies, thus making them more likely to include environmental lessons in their instructional programs.

In the case of secondary students, those who do not have a natural tendency to gravitate toward science courses often become interested in science through an environmental approach—the increase in popularity of integrated science courses and corresponding low numbers of students enrolling in traditional chemistry and physics courses illustrates this. This brings more students into the study of science. Although it is perceived by some that such courses "water down" science, it may be more challenging to teach science through studying an integrated system such as the environment. To do so, one needs a broad background in all the sciences, and to be able to link concepts across science disciplines. It seems that few faculty and high school teachers feel comfortable in doing this, perhaps because they have strong content understanding in quite narrow fields and thus, only feel comfortable teaching their own specific discipline. This compares to the same discomfort that elementary teachers feel at teaching science, for which they feel unprepared.

CURRENT STATUS OF EE IN TODAY'S EDUCATION SYSTEM

Despite the large selection of EE curricula now available, despite access to a whole wealth of EE information on the World Wide Web, and despite efforts of individual agencies and organizations to bring EE into the education reform efforts of Goals 2000, the majority of school districts list no subject

Hands-on learning at the UCLA Ocean Discovery Center.

called "Environmental Education" in their school curricula. Since most EE curricula projects have been developed by agencies outside the formal education system, the discipline tends to be relegated to the sidelines. Little effort has been made to bring EE into the core curriculum. In addition, despite the recent flurry of activity to develop content standards in academic disciplines, EE has received no such attention. Perhaps this is not all bad. If EE is to be included in the main curriculum, it must be included in the main curriculum standards and not separated by standards of its own. However, in the new State Science Education Standards, there is no mention of environmental science (although there is a very strong strand of ecological standards across the grade levels). It will be left up to the teacher to weave in the environmental perspective.

On a more positive note, one goal of the large NSF-funded Los Angeles Systemic Initiative (LA-SI) is to establish an Integrated Science Program in all LAUSD secondary schools. Since environmental studies provide a rich integrated system, teachers have designed many of their integrated programs around a study of the environment, especially the urban environment. An example of such a program is the Venice HS program on Urban Science. Integrated Science is now accepted as a science course in the A-F requirements for UC entrance. Another positive move toward implementing more EE in secondary classrooms is the new Advanced Placement (AP) Environmental Science course being offered for the first time this year.

COMPONENTS OF AN EE CURRICULUM

Consider again the three components of EL listed at the beginning of this article. We see that although EE curricula usually address the content behind environmental issues, it is more often the attitude and the action components that teachers and students alike will appreciate, get involved with, and remember. It is difficult and challenging, especially at the elementary level, for teachers to focus on science concepts behind the issues. Even at the secondary level, where curricula explain science concepts clearly, it is too often the social and behavioral components that students find interesting. This contributes to the myth that an environmental focus "waters down" the scientific content in EE courses, and leads to lack of support by more traditional departments. However, an environmental issue often provides an excellent way to motivate students to learn more—acid rain triggers student interest in understanding acids and pH. This triggers questions such as what does pH mean? What acids are formed in the environment? Why? How? Why and when are hydrogen ions dangerous? Teachers must then teach the traditional concepts about acids and bases. Too often this last step is not taken. But why?

PREPARATION OF SCIENCE TEACHERS

It is challenging to teach science well both in elementary and secondary grades. Not only must teachers have a strong, broad background in science and be able to identify and clarify science concepts they want their students to learn, but they must also present the material in a way that enables all their students to learn—not simply those who have a flair for the discipline. And as more information is added to the body of science, the task

An increasing number of opportunities for teachers and students to conduct investigative science are available through electronic networks linked through the world wide web.

escalates. Too often, teachers will stop when they have gained their students' interest and not pursue the more difficult challenge of teaching complex content.

Local science education reform programs have addressed this concern by offering environmental programs that strengthen teachers' backgrounds, while helping them identify and use effective instructional methods. The CSP-UCLA Science Project and Project ISSUES from UCLA/Center X, provide content background in urban science, and the UCLA Department of Organismic Biology, Ecology, and Evolution (OBEE) new program SSWIMS (Science Standards With Integrated Marine Science) updates participants' backgrounds in marine science. These programs help teachers develop leadership expertise for disseminating effective strategies to their peers. UCLA's Stunt Ranch Santa Monica Mountains Reserve is also developing opportunities for EE and research for local teachers and students. In addition, an increasing number of opportunities for teachers and students to conduct investigative science are available through electronic networks linked through the World Wide Web. Programs such as those administered by Cornell University encourage students to gather data on specific birds (http://birdsource.cornell.edu); students can track butterflies through Monarch Watch (http://www.monarchwatch.com); and schools can become involved in recording weather data across the nation through Project GLOBE (Global Learning and Observations to Benefit the Environment), a program initiated by Vice President Al Gore.

But in-service programs such as these cannot produce the required quality of science education alone. Universities must also help prepare teachers. This is especially true for environmental science where we are rapidly increasing our understanding of the science content.

GRADING LOCAL EFFORTS

Not every local EE effort has been mentioned in this report—there are many of note. There are also many individual teachers who make extraordinary efforts to ensure their students have opportunities to understand the environment, and the role they play in it. **Their individual efforts deserve an A grade. But EE has not yet taken the major place in the curriculum it deserves; hence current efforts in Southern California rate only a C.**

Janet M. Thornber, Director of UCLA Programs for Science Teachers at Center X in UCLA's Graduate School of Education and Information Studies, also co-directs the UCLA Science Project, one of 12 sites of the California Science Project (CSP) administered through the UC Office of the President. Ms. Thornber's work is dedicated to teachers and students in those schools targeted by UCLA to increase the pool of UC eligible students, especially those from traditionally disadvantaged backgrounds. Over the past 15 years, Ms. Thornber has received science education grants from the National Science Foundation, the Eisenhower Program, and other agencies to develop programs for Los Angeles teachers of all grade levels. Many programs have used environmental science as a vehicle for helping teachers and students relate academic science to their own world experiences. Ms. Thornber received a BSc Honors degree in Biochemistry from the University of London, England and an MSPH in Nutritional Sciences from UCLA's School of Public Health.

About the UCLA Institute of the Environment

Formally established in 1997, UCLA's Institute of the Environment grew out of the need for a campus unit dedicated to facilitating connections among the many different and divergent fields relevant to environmental research and teaching. Understanding the environment requires inquiry that transcends discipline-specific approaches. Whereas most university-based environmental programs are affiliated primarily with a single department or school, the IoE is an autonomous unit that works campus-wide to add new dimensions to environment-related research, teaching, and community outreach. The IoE brings together UCLA's diverse environment-related programs, providing coordination and integration, and making such programs more visible and effective on campus, as well as in the broader community.

THE IOE'S OBJECTIVES ARE:

- To develop multidisciplinary academic programs that address the full breadth of environmental issues facing today's society;
- To stimulate innovative and integrative interdisciplinary research on local, regional, and global environmental processes; and

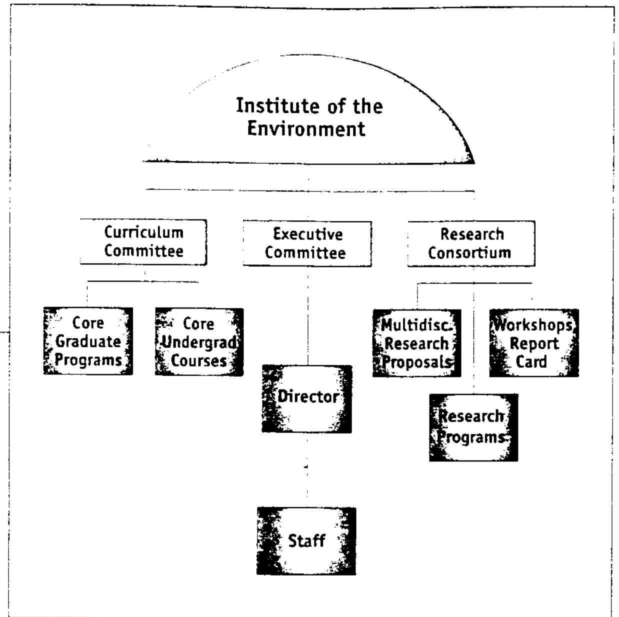
- To use collaborative problem-solving to strengthen UCLA's effectiveness in serving the community.

DISCOVERY-BASED LEARNING

To enhance the educational experience for UCLA students at all levels and in many fields, the IoE has the goal of incorporating environmental issues into every aspect of learning.

- The IoE played a major role in implementing a comprehensive overhaul of the general education curriculum in UCLA's College of Letters and Science. IoE faculty developed the first yearlong cluster course—Environment 1A, "The Global Environment: A Multidisciplinary Perspective"—which had its debut in the 1997-98 academic year.
- The IoE is developing environmental minors in six areas of concentration: engineering, life sciences, physical sciences, public health, public policy, and social sciences.
- In coming years, the IoE will initiate interdisciplinary graduate programs spanning a wide range of environmental topics.

Additionally, UCLA's Stunt Ranch Natural Reserve provides access to natural laboratory settings in the nearby Santa Monica Mountains, and the Marine Science Center's research vessel, "Sea World UCLA," enables students to collect data at sites in the Santa Monica Bay, Channel Islands, and Southern California Bight. The IoE encourages students to supplement classroom study by participating in field research throughout the Los Angeles area, gaining hands-on insights into air, land, and water issues affecting Southern California and beyond.



RESEARCH ACTIVITIES

The IoE fosters large-scale, multi-investigator, interdisciplinary environmental research by bringing together campus scholars as well as experts from local government and businesses. These broad-based investigations seek practical answers to complex questions about preserving natural resources, while still providing services for the community. They also present valuable opportunities for students to learn in the context of discovery.

- Our landmark Watershed project integrates the meteorology, hydrology, chemistry, biology, and coastal oceanography of the Los Angeles basin to address a host of issues related to water quality, availability, and management.
- The GLOBE (Global Observations to Benefit the Environment) project brings together faculty from the graduate School of Education and Information Studies and the Departments of Atmospheric Sciences, Biology and Geography to help local K-12 teachers lead students through scientific exercises, using actual instruments to record and interpret meteorological data.
- We have obtained funding from NASA to create an Environmental Remote Sensing Research Laboratory (ERRL) at UCLA. Offering state-of-the-art image-processing and computational services, the ERRL will support researchers involved in the growing field of environmental observation from space.
- The Lower Malibu Creek and Malibu Lagoon Resource Enhancement and Management Project is collecting data about the complex physical processes occurring in the largest watershed that drains into Santa Monica Bay. The aim is to identify strategies for preserving and restoring these vital and irreplaceable coastal resources.
- Over the past several years, researchers at the IoE in the natural and social sciences have been developing computer models that characterize various aspects of human-climate interactions in the Los Angeles Basin. One central theme has been the urban water cycle, which serves as an integrating metaphor linking five research sectors: human water use, coastal water quality, land use, regional meteorology, and regional air quality. With funding from the NSF, statistical tools are being developed to assess uncertainties in these computer models and provide statistical diagnostics to help improve how well they perform. The statistical procedures being developed also have wider applicability in part because they are embedded of a broad strategy for how to evaluate computer simulation models in a number of fields.
- Support from the California Sea Grant College System is enabling IoE researchers to design the first Model of the Southern California Coastal Ocean capable of resolving three-dimensional circulation patterns and integrating the most important features of biogeochemical and particulate dynamics.

UCLA Institute of the Environment

- Funded through the EPA, the Multi-level Statistical Models project extends existing methods to provide new techniques for working scientists. The goal is to assist in the process by which scientists try to generalize their findings from "case studies" or other special purpose investigations. Normally, generalizing from such research can sometimes be rather risky because it is difficult to know whether the findings apply to settings different from the ones actually studied. Since much of the research undertaken by the IoE is based in Southern California, the new statistical tools may help to indicate which finding only apply locally and which may have broader implications. The extension of statistical multilevel models include: 1) multiple response variables, 2) non-linear functional forms, 3) missing data, 4) disturbance covariance matrices allowing for temporal and spatial dependencies and 5) latent variables. At the end of the project, there will be software available for the techniques being developed that will run on a number of different platforms.
- With generous assistance from Intel Corporation, the IoE has built a Regional Environmental Assessment Laboratory and Geographical Information System (REAL/GIS) that will be accessible on campus as well as on the Internet. The REAL/GIS will provide scientists, planners, and the public with access to one of the largest and most diverse environmental databases for a major urban area.
- The IoE is collaborating with the Los Alamos National Laboratory to establish a Center for LIDAR environmental and atmospheric research. The center will develop a mobile, eye-safe system using lidar observations (a technique, similar to radar, that employs pulsed laser light instead of microwaves) to inform regional air quality forecasts.
- The IoE is a leader in earth system modeling, a holistic approach for studying global climate change by examining relationships among the atmosphere, land surfaces, oceans, and biogeochemical cycles.

"What is unique about the Institute of the Environment as an environmental program is its interdisciplinary breadth. It encompasses all of the major academic fields on a major university campus. Other university-based programs tend to focus on a single discipline, like engineering or agriculture. The IoE is broadly interdisciplinary to the same extent that our society is."

Richard P. Turco, Ph.D.
Founding Director, Institute of the Environment
Professor of Atmospheric Sciences

HOW TO REACH US:

The Institute has established a new web site. Our activities are routinely updated on the site, and we announce events and other activities of interest to those concerned about the environment. Contact us through our web site and sign our Guestbook. We welcome your feedback.

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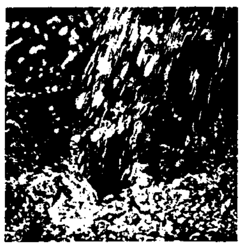
RC 1998 Revisited

WASTEWATER TREATMENT

We received several comments on the Wastewater article. The Los Angeles County Sanitation Districts (LACSD) (James Stahl) felt they had good reasons for delaying the decision to provide secondary treatment at their Joint Water Pollution Control Plant in Carson. They noted the DDT contained in the sediments off White's Point may someday be reintroduced into the environment, where they will do additional damage. Presently the DDT sediments are covered by sediment from the release of primary effluent. Continued release of primary effluent might keep the sediments covered and prevent their release. The U.S. EPA recognized the need to prevent DDT from reentering the environment, but felt the damage from primary effluent was greater than the risk of DDT release. A comment from Professor Stenstrom, the author of this article, is that the scientific merits of both sides of the debate were never entirely understood. This resulted from a lack of a disinterested third party. Scientific arguments offered by LACSD were never credible to the environmental community because of a real or perceived conflict of interest. The savings of avoiding secondary treatment would accrue to LACSD and its users. A proposal for an ocean waiver by a neutral third party, without financial interests, might have been received differently. The issue of DDT contaminated sediments remain, and will haunt us for some time to come.



The Bureau of Sanitation, City of Los Angeles (Judy Wilson) wrote to say they appreciated the "A" they received for inland plants, but believed they now deserve an "A" for the Hyperion Wastewater Treatment Plant. They cited the difficulties associated with its expansion and improvements, including differences of opinion with regulatory agencies about the design and method for its expansion. The Report Card was a retrospective look at the wastewater treatment by the Hyperion Plant since the Clean Water Act Amendments in 1972. The grade was based on the performance during this entire period, as opposed to more recent events, and the author stands behind this grade.

However, there is a new story to tell with respect to the Hyperion Plant. The plant began full secondary treatment in December, 1998, two months ahead of its final construction schedule. The City and guests celebrated the plant's opening on May 15 in a ceremony attended by 1500 people. The City announced that the plant was constructed ahead of schedule and at a cost significantly under budget. The completion of the plant will end a 22-year lawsuit over its construction.

The construction of the plant is a tribute to the City. It is a "top 10" plant in terms of its size. There are few plants larger in the United States. The most outstanding aspect of the Hyperion construction is the very tight construction schedule, and the small area occupied by the plant. The plant provides not only for secondary treatment, but anaerobic sludge digestion and sludge dewatering. The digesters produce methane gas which is burned at the Scatter Good Power station to produce electricity for Hyperion at significant savings. Hyperion also provides approximately 20 million gallons per day of reclaimed water for the West Basin project, and additional reclamation will occur in the future. Hyperion now has the capacity to treat the City's wastewaters, including the high flows that occur in winter, as well as low-flow diversions, which will protect our beaches in the summer.

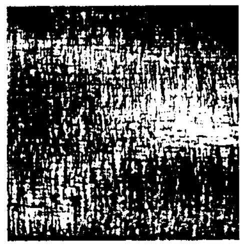
Hyperion may not be the largest plant, but it is probably the largest plant in the smallest land area of any plant in the world. This results in part because of the use of high purity oxygen for aeration, but mostly from clever design. Its construction required delicate timing because there simply was not room for normal construction practices. It was also necessary to keep the old secondary plant operating until it could be replaced by the first completed portion of the new secondary plant.

In the late 1970's and early 1980's, engineers reviewed the old Hyperion Plant, the requirements for the secondary treatment, including sludge disposal, and said that "it can not be done." Now the City has done it, and we have to thank the City's new team for accomplishing this great task.

Michael K. Stenstrom, Ph. D.
Professor, Civil and
Environmental Engineering,
School of Engineering
and Applied Sciences

WETLANDS

Ballona Wetlands. Although there has been little change to the wetland area at Ballona Wetlands, there continues to be a great deal of political activity surrounding the preservation and restoration of the wetlands. A coalition of environmental groups continues to protest the plans for Playa Vista, a $7 billion residential and commercial development, and especially the involvement of DreamWorks. In summer 1998, a federal judge issued an injunction that stopped work on a 16-acre freshwater marsh being constructed to regulate and treat freshwater runoff before it enters the salt marsh, but not other construction activities; the ruling is being appealed. The plans for the salt marsh restoration have not yet been released.



Malibu Lagoon. UCLA has just completed a study of the Malibu Creek Watershed, led by Professors Richard Ambrose and Tony Orme. The study has improved our understanding of the hydrology and barrier beach dynamics as well as refined our ideas about the evolution of the wetlands. The study also evaluated numerous alternatives for managing the resources of the watershed and provided preliminary wetland restoration plans and recommendations for several areas in the lagoon area. The recommendations will soon be considered by the community. The Southern California Wetlands Clearinghouse has given Malibu Lagoon a high priority for funding for restoration, so planning for additional restoration in the area should begin soon.

Richard F. Ambrose, Ph.D.
Professor, Environmental Health Sciences,
Director, Environmental Science and
Engineering Program,
School of Public Health

AIR QUALITY

Response received from the South Coast Air Quality Management District

According to its opening *Letter From the Director*, the Institute's first Report Card was intended to "document progress and regression" in four environmental areas. However, significant strategic accomplishments were omitted from both the grading analysis and the discussion of our region's air quality programs. Taken together, these new tools quietly paved the way for increased public health benefits, continued reductions in ambient emission levels, and improved cost-effectiveness for air pollution control measures.

For example, unmentioned in the air quality article were two benchmark accomplishments that occurred in the year under review, 1997:

- **Early rewards from the AQMD Governing Board's Environmental Justice Initiatives**, including initiation of an unprecedented, comprehensive mobile monitoring effort measuring air toxics exposure to more than 50 compounds; targeted Town Hall meetings to resolve chronic nuisance emissions in previously under-represented neighborhoods (such as low-income communities of color); and enhancement of New-Source Review for cancerous and hazardous air contaminants.

- **Adoption of far-reaching fugitive dust controls, to address some of the worst fine-particulate pollution in the nation**, including measures to significantly reduce suspended road dust, which comprises one-third of the ambient particles smaller than 10 microns in diameter, known as PM10—strongly linked to respiratory disease and increased deaths. The measures adopted required a comprehensive approach tying together technical research and implementation among the construction industry, scores of street maintenance operations by local governments, and Southland agriculture.

In addition, that year also saw progress on reducing emissions from solvents, petroleum coke handling, restaurant chain-charbroilers, boilers and water heaters, and refinery flaring operations. Beyond these formal regulatory actions, progress was made on other fronts:

- Enhancement of socioeconomic assessment tools to provide decision-makers with more complete understanding of the potential benefits and costs of alternative air quality solutions;

- Market acceleration for a host of low-emission technologies and fuel systems developed through public-private partnerships under the internationally recognized Technology Advancement program; and

- Improved dialog to clarify enforcement priorities, highlight compliance issues, and streamline working relationships among regional, state, and federal bodies.

Finally, critical seedwork was taking place to improve the body of scientific knowledge on air pollution. This key seedwork included expansion of the region's air monitoring network, practical demonstrations of waterborne cleaners and low-emission paints, and important research on diesel exhaust—later declared as a toxic air contaminant and a significant public health threat.

1999's air quality successes have included heightened focus on ways to mitigate disproportionate impacts of poor air quality on children and those with pre-existing health problems, and a landmark rule controlling emissions from architectural coatings, a significant source of ozone-precursor emissions in the South Coast. Today's action focus would not have been possible without the active public and small-business feedback solicited over the past two years.

Southern Californians can measure their progress in the war on smog by comparing 1977's 121 Stage 1 smog episodes to the single episode in 1997. And though El Nino showers helped our air that year: so did diligent efforts that may have escaped the attention of the Institute. The prospect for the future is blue sky by the time that federally mandated clean air standards are to be achieved.

Barry R. Wallerstein, D. Env.
Executive Officer, South Coast AQMD

Response to SCAQMD

We welcome the SCAQMD's response as part of an open dialogue concerning critical environmental issues confronting the region. However, far from reviewing only a single year, 1997, as stated by the District, the Air Quality article in the 1998 Report Card provided a much larger perspective on the 50 year effort to reduce air pollution in Southern California. Within that larger framework it was not possible to list every recent accomplishment of the local air pollution agency, although most of its major achievements were cited. Clearly, many of the recent projects listed in the District's response to our article are laudable and, in several cases, long overdue. Nevertheless, it remains unclear whether the present overall efforts by the District will in fact produce "blue skies" in the next decade, as promised in their letter. For example, while taking credit for there being only a single Stage I ozone alert in 1997, the District's letter fails to mention that in 1998 the number of Stage I alerts surged to 12. Whether this represents a short-term setback, or the beginning of a reversal in the long-term decline in ozone, will only be revealed over time. We intend to revisit the District's Air Quality Management Plans, and the status of air quality in Southern California, no later than the 2003 Report Card. At that time, the additional years of air monitoring data will tell us whether the District's rosy projections were justified.

Arthur M. Winer, Ph.D.
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1999 Southern California
Environmental Report Card
UCLA Institute of the Environment

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Figures/Diagrams
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U.S. EPA Database (28)
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Malibu Creek Watershed

Conserving Our Natural Resources

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Contents

Introduction	*1*
Background Information	*3*
Water Quality Concerns	*8*
Subwatersheds	*12*
Hidden Valley	*13*
Westlake	*14*
Lindero Canyon	*15*
Palo Comado	*16*
Las Virgenes	*17*
Triunfo Canyon	*18*
Cold Creek	*19*
Malibu Creek	*20*

INTRODUCTION

Pollution of Malibu Creek and Malibu Lagoon has been causing concern for many years. In the late 1970's, an areawide plan for the South Coast area of California listed urban runoff, rural runoff, agricultural activities, recreational activities, septic tank systems, and unsewered communities as potential non-point sources of pollutants.

Nearly 20 years later these same sources are still a concern. The State of California, in its 1994 Water Quality Assessment, identified Malibu Lagoon, Malibu Creek and two of its tributaries, and several lakes in the Malibu Creek watershed as water bodies with at least some degree of water quality impairment. The assessment also identified "non-point" sources — sources such as overland storm runoff or seepage, which carry pollutants to the stream system via diffuse pathways -- as a major part of the problem. In addition, the use of imported water has greatly increased summer flows in the last 30 years.

Recognizing the problems, theResource Conservation District of the Santa Monica Mountains (formerly theTopanga-Las Virgenes Resource Conservation District) sponsored development of a natural resources plan for the watershed, with emphasis on water quality and quantity. The plan was prepared by the Natural Resources Conservation Service.

It was clear from the outset that a great many groups and individuals would be involved in the planning process. The RCD joined with the Santa Monica Bay Restoration Program to coordinate the efforts of the interested parties. Because of the diversity of viewpoints and concerns, a formal mediation effort was undertaken. That effort has led to a more widespread awareness of the connection between land use activities throughout the watershed and water quality in the creeks and lagoon.

The participants also developed a list of action goals. Some of these are addressed in the natural resources plan. Others are being pursued in other ways.

The plan:

1. Identifies and describes local water quality and quantity problems, including alteration of the flow regime.

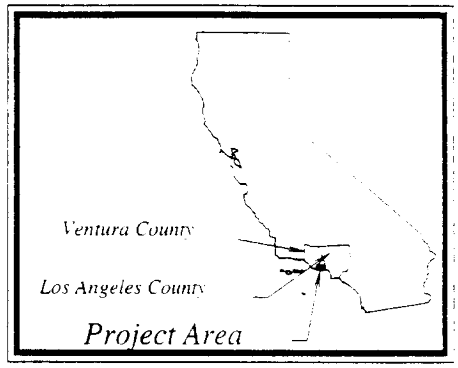
2. Evaluates and compares treatments to reduce the water quality problems linked to surface runoff.

3. Identifies possible implementation strategies and funding sources.

The complexities of the Malibu Creek watershed, the current level of understanding, and the differing points of view of interest groups means that there is no single combination of broadly applicable treatment options. Each site needs to have specific treatments designed for its particular conditions. The information and ideas in the plan will assist local leaders and land users in their efforts to improve water quality.

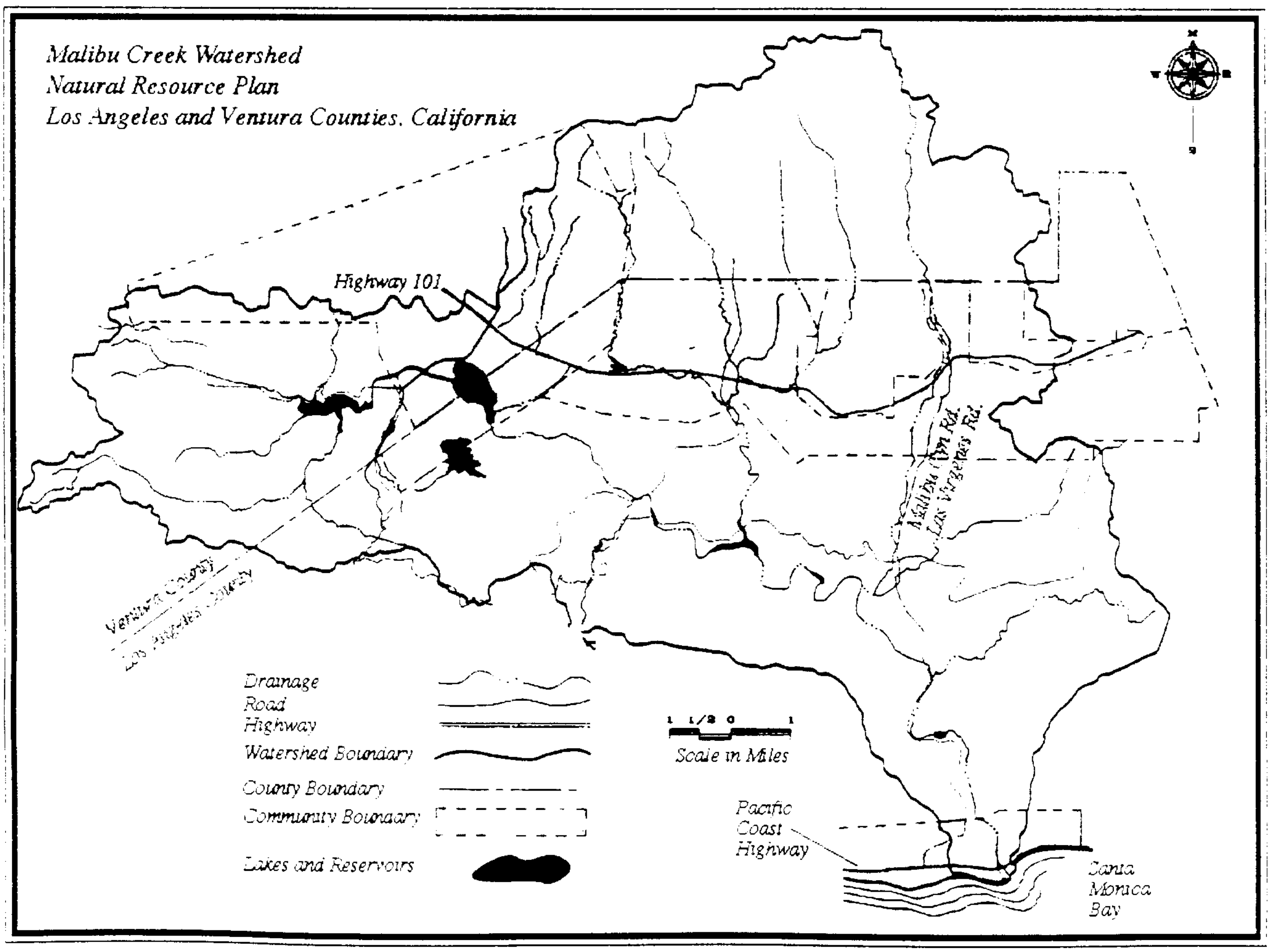
This report is a brief summary of the information in the natural resources plan. Copies of the complete plan may be obtained by contacting the RCD of the Santa Monica Mountains.

SETTING



The Malibu Creek Watershed is located about 35 miles west of Los Angeles. The creek and its tributaries drain a 109-square-mile area of the Santa Monica Mountains and adjacent Simi Hills. Approximately two-thirds of the watershed is in Los Angeles County and the rest is in Ventura County.

Malibu Creek drains into Malibu Lagoon and from there into Santa Monica Bay. Santa Monica Bay is one of three estuaries in California currently in the National Estuary Program. The program is an interagency effort administered by the U.S. Environmental Protection Agency. Its purpose is to protect and improve coastal water quality.



Location Map

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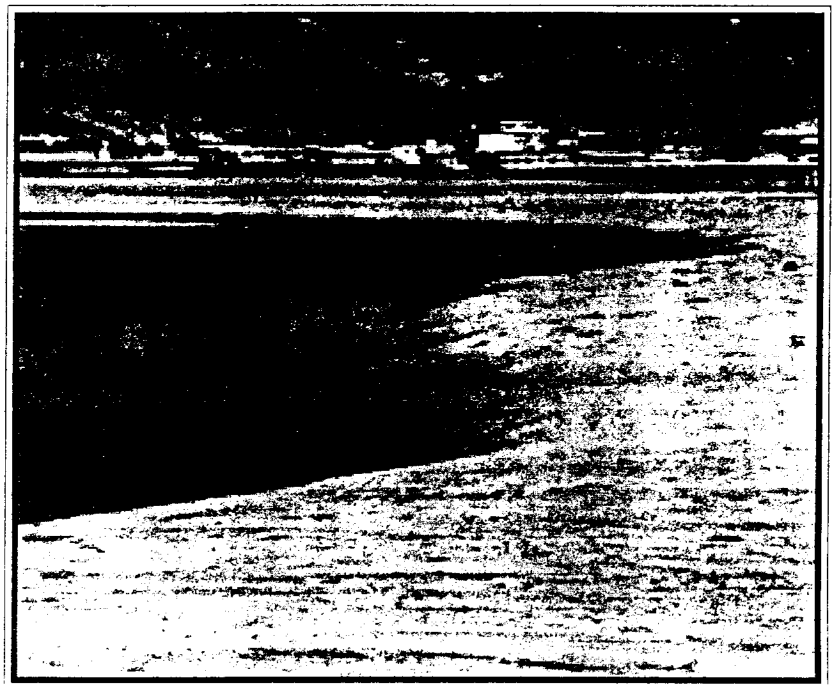
Malibu Beach is internationally known for its prime surfing conditions and is a popular destination for beachgoers and vacationers. The beach is part of the highly valued recreation area along the Santa Monica Bay coastline. Malibu Lagoon State Beach is located at the outlet of the lagoon.

Malibu Lagoon provides valuable estuarine habitat. It also serves as an outdoor classroom and offers many recreational opportunities. It is one of the few lagoon-type estuaries draining into Santa Monica Bay.

The lagoon's outlet to the ocean is closed off most of the year by a sand and gravel bar. It opens only when large storm flows come down the creek or when smaller or continuous flows cause the lagoon to overflow. The bar is often breached mechanically when there has been an extended period of low flow. The currents in the bay rebuild the bar after only a few weeks.



Sand and Gravel Bar

Two major highways cross the watershed: the Ventura Freeway (U.S. 101) and the Pacific Coast Highway (State Highway 1). More than 150,000 people commute along the Highway 101 corridor each day, and another 20,000 use the Pacific Coast Highway and the Malibu Canyon-Mulholland Highway corridors. The 1990 population within the watershed was about 90,000. Over 40 percent of the work force holds high-end white collar jobs, such as executive or professional specialty jobs. Forty percent of the housing in the watershed in 1990 was constructed after 1980.

The watershed consists of a number of subwatersheds. Land use and related resource issues vary significantly from one subwatershed to another. The subwatersheds are described later in this report.

LAND OWNERSHIP AND USE

Evidence indicates that the Malibu coast has been inhabited by humans for more than 10,000 years. Within recent history, grazing was the predominant land use in the watershed. Modern expansion of the Los Angeles metropolitan area and consequent development pressures have significantly reduced grazing and increased recreational activities and urban development in the watershed.

The watershed is located near a major metropolitan area, yet includes large areas of open space. Despite the extensive urbanization, large areas remain undeveloped in the upper watershed. A significant portion of the 69,900-acre watershed is in public ownership, including 6,700 acres in the Santa Monica Mountains National Recreation Area and 8,500 acres owned by the State Department of Parks and Recreation. The numerous parklands provide opportunities for hiking, mountain biking, fishing, horseback riding, camping, bird watching, and other outdoor activities.

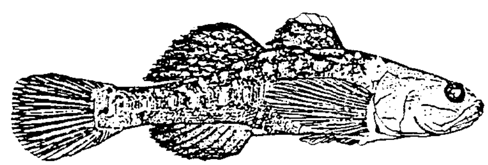
Land Use	**Acres**
Orchards	30
Pasture	1,520
Field Crops	260
Confined Animals	320
Urban	8,310
Rural Residental	2,800
Natural Areas	55,300
Golf Courses	540
Water	450
Other	380
Total	**69,910**

Recent development has resulted in the conversion of large blocks of middle and upper watershed open space to urban landscape. The cities of Malibu, Calabasas, Agoura Hills, Westlake Village, and Thousand Oaks lie partly or entirely within the watershed. All have expanded significantly in population since the 1990 census. Several additional large subdivision projects have been proposed and are now pending before the Ventura and Los Angeles County Planning Commissions. The city of Malibu lies along Santa Monica Bay at the outlet of Malibu Creek.

PLANT COMMUNITIES AND WILDLIFE

Over 600 native species and 200 introduced species of plants are known to exist in the watershed. The predominant habitat types include coastal oak woodland, mixed chaparral, coastal scrub, coastal salt marsh, and annual grassland, with inclusions of riparian and other habitat types.

The watershed supports an abundant and diverse wildlife community, which reflects the diversity of the vegetative communities. More than 450 species occur, including 50 mammals, 384 birds, and 36 reptiles and amphibians. The wildlife populations are unique in their proximity to one of the largest urban areas in the United States.



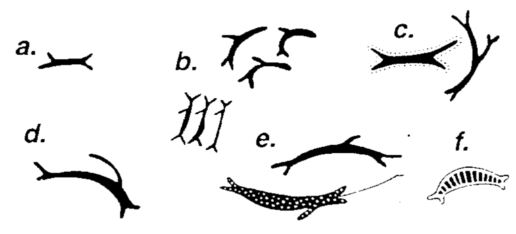
Tidewater Goby

Fish species include the southern steelhead, tidewater goby, and arroyo chub. Non-native fish include goldfish, largemouth bass, and bluegill. The steelhead run in Malibu Creek is the southernmost documented run in the United States.

At the time the natural resource plan was published, one plant, one fish, and nine bird species that are permanent or seasonal residents in the watershed were federally listed as threatened or endangered. Nineteen additional state-listed species may occur there. A number of additional species are candidates for listing. The tidewater goby, the federally listed endangered fish, had ceased to exist in Malibu Lagoon, but was reintroduced in 1991 by the Resource Conservation District of the Santa Monica Mountains. The goby is found only in coastal, brackish water habitats. The Malibu Creek population of the Southern California steelhead has been included in a recent addition to the federal list of endangered species.

CULTURAL RESOURCES

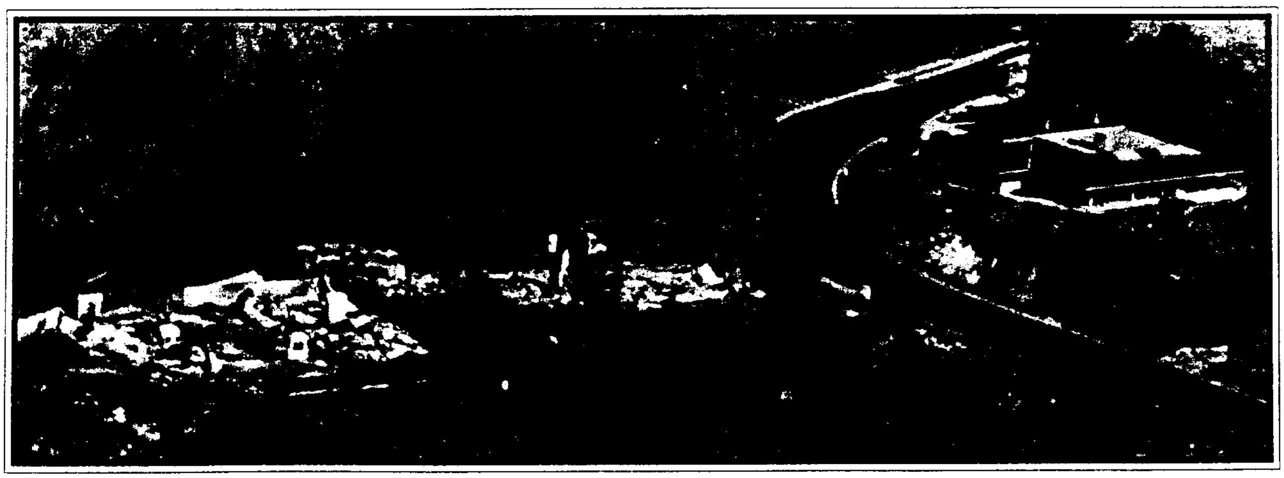
The Santa Monica Mountains have one of the highest densities of archaeological sites of any mountain range in the world. The National Park Service estimates that there may be over 300 sites within the watershed. There are at least two Chumash pictograph sites, and more are likely. These are of extreme public interest, yet are religious and sacred sites for Native Americans. Other sites include sacred sites, bedrock mortar sites, villages, middens, and burial sites.



Aquatic designs from nine sites in the Chumash country
a. Purisimeno; b. Ynezeno;
c. Cuyama; d. Canalino;
e. Ventureno; f. Emigdiano

FIRE IN THE WATERSHED

Fire is one of the natural processes in the local ecosystem. Nearly all areas in the watershed have burned at least once since 1925, and a substantial portion has burned three or four times. The most recent fire was the Old Topanga fire of November, 1993. Human encroachment into fire-prone areas requires fire management planning that recognizes the reality of the fire regime.



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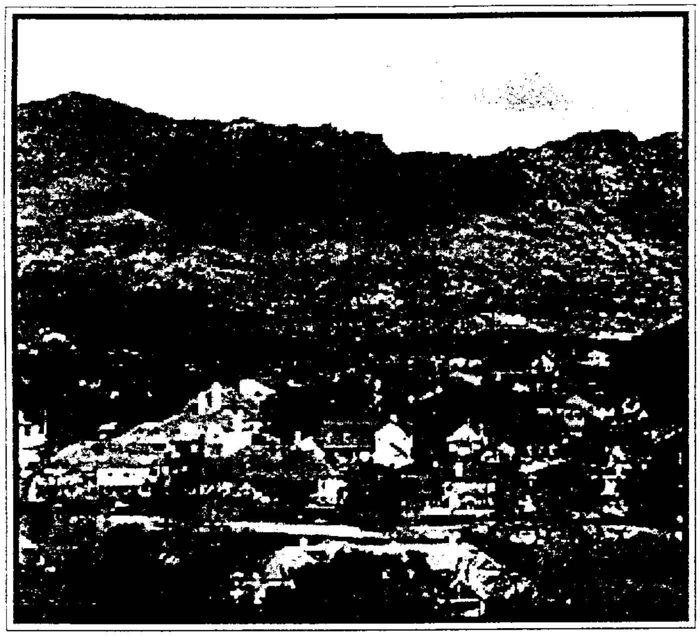
THE WATERSHED ECOSYSTEM



The development in the watershed has stressed and changed ecosystems. Buildings, pavement, lawns, and highways have replaced natural habitats. Imported water has allowed humans to increase their population beyond the watershed's natural sustainability. Increased stream flows have changed riparian and aquatic systems. Even though the increased flows are thought to benefit steelhead, they may also have adverse effects, such as elevated water temperatures caused by discharges, non-continuous stream flows, and water quality impacts.

IMPAIRED WATER QUALITY

Beneficial uses of the waters of the Malibu Creek Watershed, and especially those of the lagoon, are being threatened by accelerated sedimentation, runoff, salinity fluctuations, nutrients, and harmful bacteria. For example, coliform levels in the Malibu area stream system often reach concentrations higher than recommended for contact recreation, a designated beneficial use for the creek. The State Water Resources Control Board has identified eight water bodies in the watershed as impaired (not meeting standards) or suffering intermediate impairment (not meeting standards on some occasions).

Impaired Water Bodies
(as listed in the 1994 State Water Quality Assessment)

Malibu Lagoon	Twenty-nine acres, impaired; eutrophication, threat of recreational impacts, and fish kills.
Malibu Creek	Six miles, intermediate impairment, and three miles, impaired; fish population decline, spawning impairment, and sedimentation.
Lake Eleanor	Eight acres, intermediate impairment, eutrophication and urban runoff.
Malibou Lake	Fifty-five acres, intermediate impairment; elevated fish tissue levels, suspected eutrophication, and sedimentation.
Lake Sherwood	One-hundred-eighty-four acres, intermediate impairment: suspected elevated fish tissue levels.
Westlake Lake	One-hundred-fifty-six acres, intermediate impairment: suspected elevated fish tissue levels and eutrophication.
Triunfo Canyon	Seven miles, intermediate impairment: suspected sedimentation.
Lake Lindero	Fourteen acres, intermediate impairment: elevated fish tissue levels.

LAND MANAGEMENT TO IMPROVE WATER QUALITY

Water quality problems in this watershed are heavily influenced by land use activities. There are opportunities to reduce non-point source pollution by improving land management practices. Appropriate treatments vary, depending upon the land use.

- **Confined animal facilities.** These create a major problem in the collection, management, and disposal of waste products from the animals. Proximity to water bodies is also often a problem.

  Confined animal facilities are usually sparsely vegetated because large numbers of animals or large animals in a small area remove or trample the plant material. Nutrients from manure deposited on the ground surface in these areas will not only leach into the groundwater but will also be transported offsite by wind and water, along with the manure and soil particles. The problem is even greater where the confinement area includes part of the creek system.

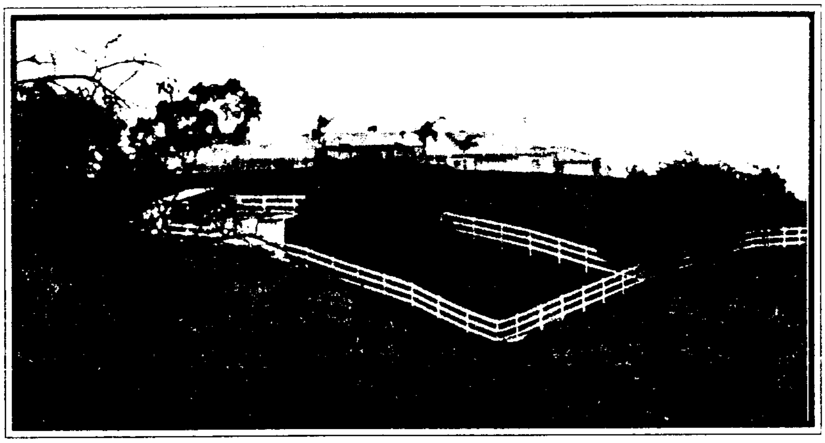
  An example of a conservation system to reduce nutrients, sediment, and runoff leaving a confined animal facility might include the following practices: a waste management system, waste utilization, roof runoff management, filter strips, and critical area planting.

- **Single-family residential areas.** Residential streets are deposition and storage areas for pollutants such as nutrients, sediments, dust, hydrocarbons and coolant from vehicles, and yard and pet wastes. These materials need to be removed from streets before rainfall carries them into the storm sewer system. This requires an effective street cleaning program.

  Nutrient use on lawns and landscaping is estimated to be two to three times the amount needed for growth. This is often due to lack of information. Water use in residential areas is also excessive for the same reason. The excess water and nutrients are either delivered directly into the storm drain system and the creeks or into the local ground water bodies. Reductions in nutrient and water use through better management and education can be cost effective for the land owner.

An example of a conservation system to reduce erosion, sediment and runoff from roads, and nutrients, sediment, and excess water leaving horse paddocks, lawns, and other landscaped areas might include the following: better road planning ,critical area planting, filter strips, a waste management system, waste transfer, residential street waste management, irrigation water management, nutrient management, and sediment basins.

- **Spaced rural residential areas.** This is a land use designation where the parcels may include a large house, landscaped ground, a horse paddock, and home orchards which are not associated with an agricultural operation. Horse paddocks averaging a half acre or more are common in the spaced rural residential areas. Water and nutrient use on lawns and landscaping is similar to that in single-family residential areas. The system of practices described for single-family residential areas could also be used in the spaced rural residential areas to reduce erosion, sedimentation, nutrients, and excess fresh water.



Spaced Rural Residential

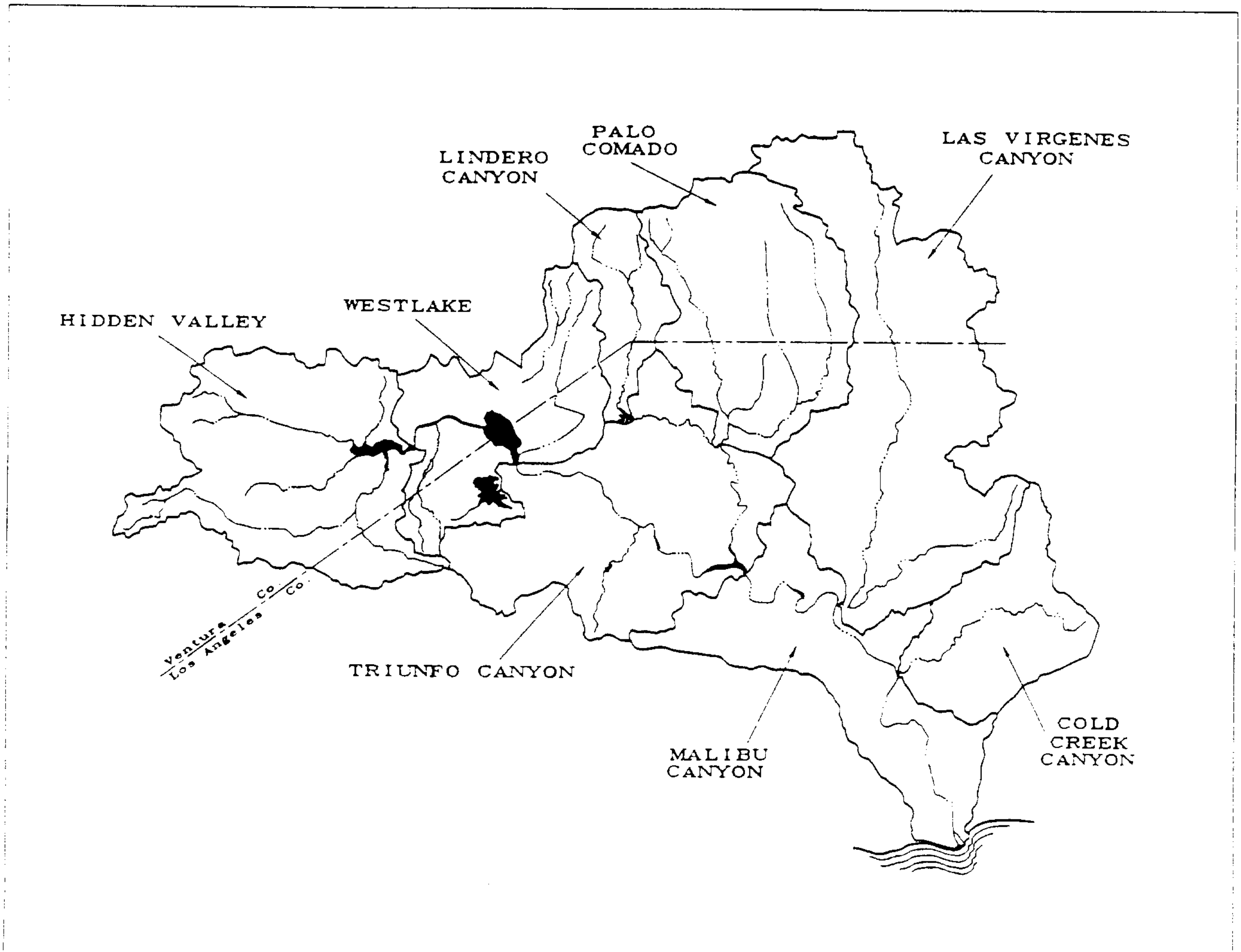
Horse paddock improvements could include distancing the paddock from streams and watercourses, controlling water from upslope areas and roofs, leaving cover on the soil surface, animal waste management and storage, and sediment control.

- **Natural areas, rural parks, and landfills.** Erosion from roads and trails in the natural areas of the watershed has been identified as a source of most of the sediment from land in this use. Similar rates are associated with roads and trails in the parks, and with landfills.

An example of a conservation system to reduce erosion and sediment caused by runoff from roads and other disturbed areas such as landfills might include the following practices: better road planning (including retirement of unnecessary roads and trails), critical area planting, sediment basins, and a program of prescribed burning.

SUBWATERSHEDS

The Malibu Creek Watershed includes eight subwatersheds that contribute to the flow and quality of water in Malibu Creek. Each subwatershed can be viewed with its own land use and resource issues, revealing how it affects the whole watershed's ecosystem. The following pages provide an overview of each subwatershed with its land use, water quality issues, and the types of treatment that would be most useful in reducing pollution from non-point sources.



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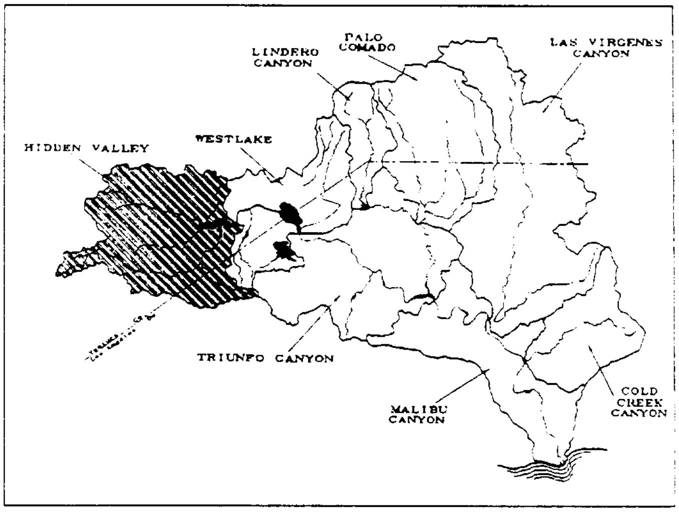
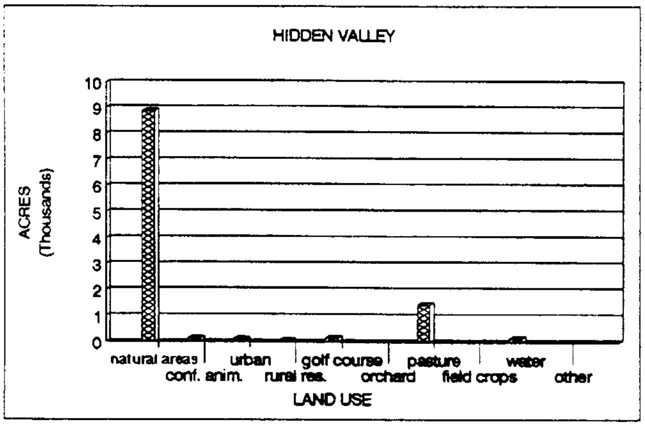
SUBWATERSHED OVERVIEW

Located in the far west portion of the Malibu Creek watershed, the 10,975-acre Hidden Valley subwatershed has an approximate population of 1,200 (Census 1990). The subwatershed is predominately natural areas with a large acreage of pasture for the raising of livestock. A golf course is located adjacent to Lake Sherwood which is the outlet of the subwatershed. The majority of the residential area is situated around Lake Sherwood. Most of the existing buildup in the subwatershed occured prior to 1980.



LAND USE



WATER QUALITY ISSUES

Major Water Body: Lake Sherwood

Possible Concerns: High levels of nutrients causing increased algae growth in lake

Possible Sources: Fertilizers, animal wastes, wildlife wastes

Designated Beneficial Uses: Municipal water use, water contact recreation*, non-contact water recreation*, warm freshwater habitat*, groundwater recharge, navigation*, wildlife habitat

* may be affected by the possible concerns

POTENTIAL TREATMENT

For Rural Land Uses:

- Filter Strips
- Waste Management Systems
- Waste Utilization
- Livestock Exclusion
- Pasture and Hayland Management
- Fencing
- Irrigation Water Management
- Nutrient Management

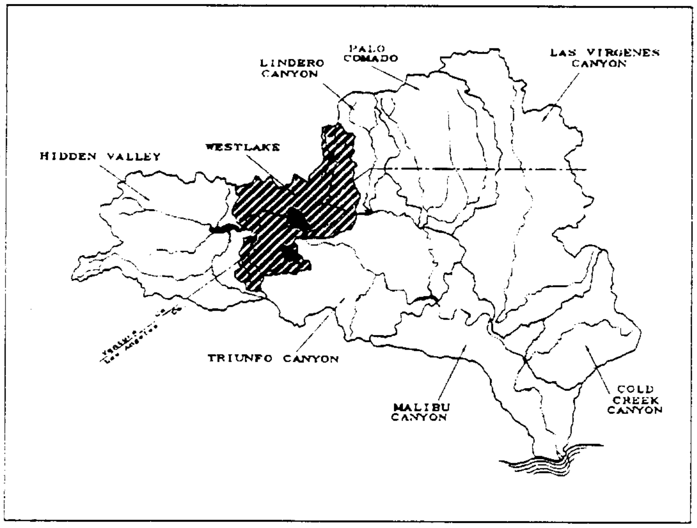
For Urban Land Uses:

- Nutrient Management
- Irrigation Water Management

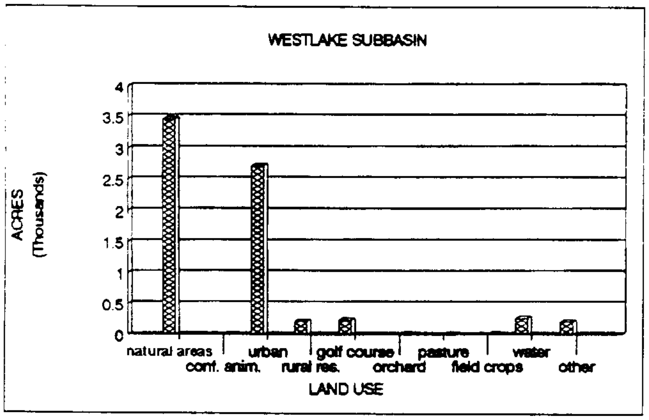
R0026409

SUBWATERSHED OVERVIEW

The 7,084-acre Westlake subwatershed contains the cities of Thousand Oaks and Westlake Village. This subwatershed is predominantly natural and urban areas. Much of the residential area is situated around the 157-acre Westlake Lake.



LAND USE



POTENTIAL TREATMENT

For Urban Land Uses:

Lawns, Golf courses, etc.

- Nutrient Management
- Irrigation Water Management

Stormwater Runoff

- Constructed Wetlands
- Filters
- Detention Basins

WATER QUALITY ISSUES

Major Water Body: Westlake Lake

Possible Concerns: Eutrophication impairment, high coliform bacteria levels have been recorded

Possible Sources: Fertilizers, urban runoff, wildlife wastes

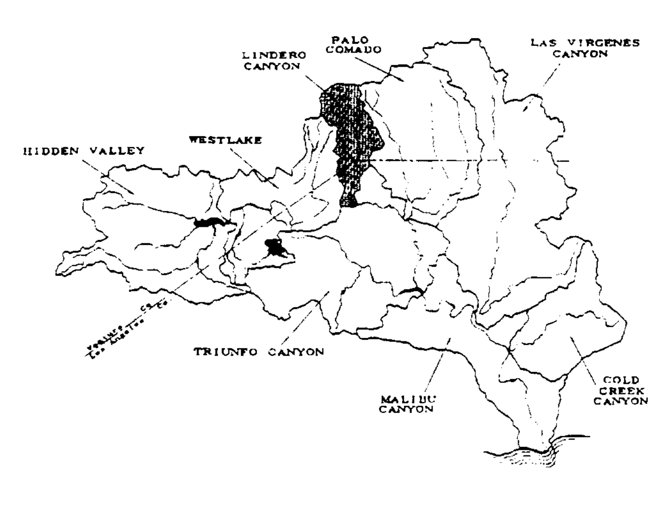
Designated Beneficial Uses: Municipal and domestic supply*, water contact recreation*, non-contact water recreation*, warm freshwater habitat*, groundwater recharge*, navigation*, wildlife habitat

* may be affected by the possible concerns

R0026410

SUBWATERSHED OVERVIEW

The Lindero Canyon subwatershed consists of 2,463 acres about equally divided between residential and natural areas. Golf courses occupy 138 acres of the subwatershed. Much of the development took place in the 1980s. The outlet for this subwatershed is the 14-acre Lake Lindero. As with subwaterhseds 1 and 2, much of the residential area is located around the lake with more residential acreage adjacent to the golf course in the northern part of the subwatershed.



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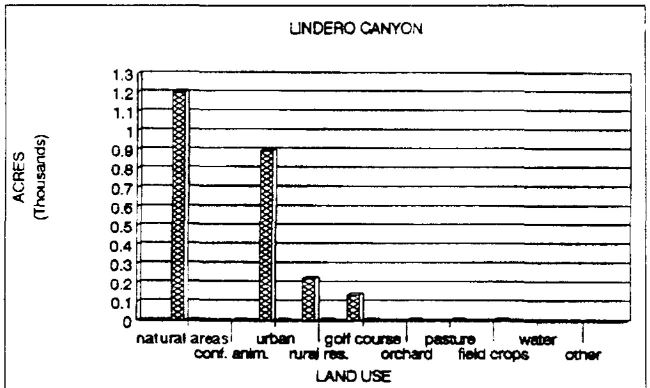


WATER QUALITY ISSUES

Major Water Bodies: Lake Lindero, Lindero Creek

Possible Concerns: High levels of coliform bacteria, sediment deposition

Possible Sources: Urban runoff, wildlife wastes

Designated Beneficial Uses: Municipal and domestic supply*, contact and non-contact water recreation*, warm freshwater habitat, wildlife habitat

*may be affected by the possible concerns

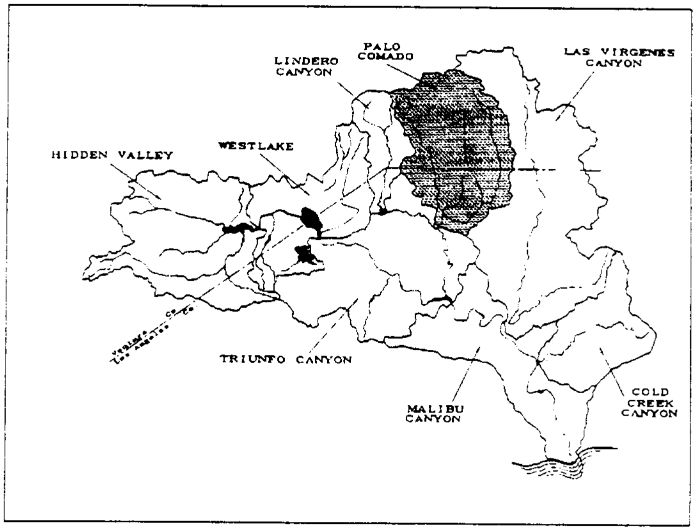
POTENTIAL TREATMENT

For Urban Land Uses:
- Irrigation Water Management
- Constructed Wetlands
- Filters
- Detention Basins
- Access Roads
- Critical Area Planting
- Sediment Basins

For Natural Areas:
- Road Retirement
- Critical Area Planting
- Streambank Restoration

SUBWATERSHED OVERVIEW

Located in the northern end of the Malibu Creek watershed, the Palo Comado subwatershed consists of 9,360 acres of mostly natural area with a large sprinkling of residential area and confined horse facilities. The majority of the population of this subwatershed lives in the City of Agoura Hills. The natural areas (6,958 acres) are in good condition and do not appear to have major problems.



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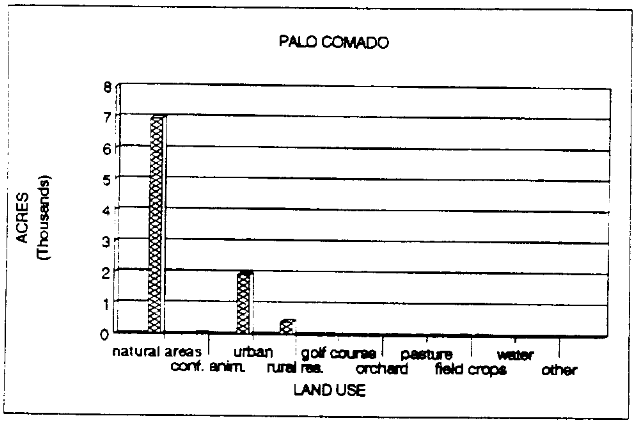


POTENTIAL TREATMENT

For Urban Land Uses:

- Lawns, Golf Courses, etc.
  - Filter Strips
  - Irrigation Water Management
  - Nutrient Management
- Stormwater Runoff
  - Constructed Wetlands
  - Filters
  - Detention Basins

For Confined Animal Land Uses:

- Waste Management System
- Waste Utilization
- Waste Transfer
- Livestock Exclusion
- Fencing
- Pasture and Hayland Management

WATER QUALITY ISSUES

Major Water Bodies: Medea Creek, Palo Comado Creek

Possible Concerns: Nutrients and bacteria in creeks

Possible Sources: Urban runoff, confined animal waste, wildlife wastes

Designated Beneficial Uses:

Upper Medea Creek: Existing uses - wildlife habitat, rare and endangered species habitat, wetlands habitat; Potential uses - municipal and domestic supply*, cold freshwater habitat; Intermittent uses - groundwater recharge*, contact and non-contact water recreation*, warm freshwater habitat

Lower Medea Creek: Existing uses - contact and non-contact water recreation*, warm freshwater habitat, wildlife habitat, wetlands habitat; Intermittent uses - municipal and domestic supply*, groundwater recharge

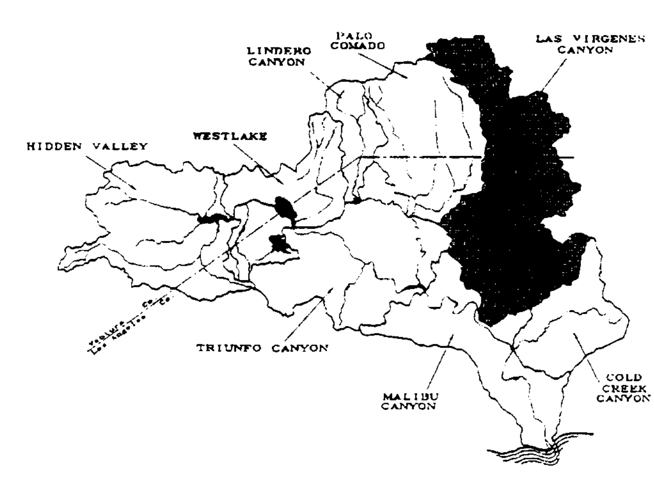
As a tributary to Medea Creek, Palo Comado Creek has the same beneficial uses as Medea Creek.

*may be affected by the possible concerns

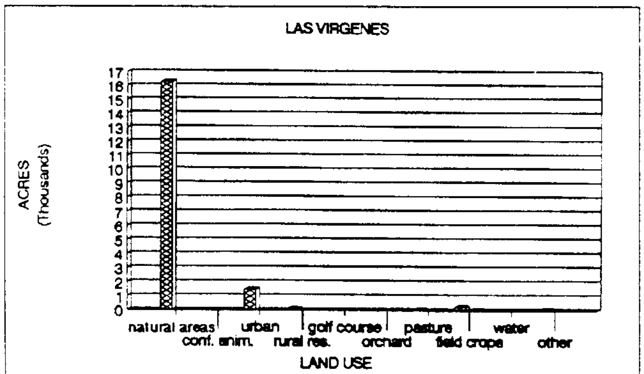
R0026412

SUBWATERSHED OVERVIEW

This 18,261-acre subwatershed is predominantly natural area with residential area as the second largest land use. There are also small amounts of orchard, pasture, and field crop acreage. Over 300 out of the total 3,766 households are on septic systems. The residential areas are scattered throughout the subwatershed as opposed to being congregated in one area. The outlet of this subwatershed is the confluence of Las Virgenes and Malibu Creeks.



LAND USE



WATER QUALITY ISSUES

Major Water Body: Las Virgenes Creek, Stokes Creek

Possible Concerns: Intermittent high bacteria and nutrient levels, low dissolved oxygen levels

Possible Sources: Runoff from natural areas, wildlife, urban runoff, septic systems

Designated Beneficial Uses: Existing uses - contact and non-contact water recreation*, warm frteshwater habitat, wildlife habitat, wetland habitat, rare and endangered species habitat; Potential uses - cold freshwater habitat*, migration*, spawning*

* may be affected by the possible concerns.

POTENTIAL TREATMENT

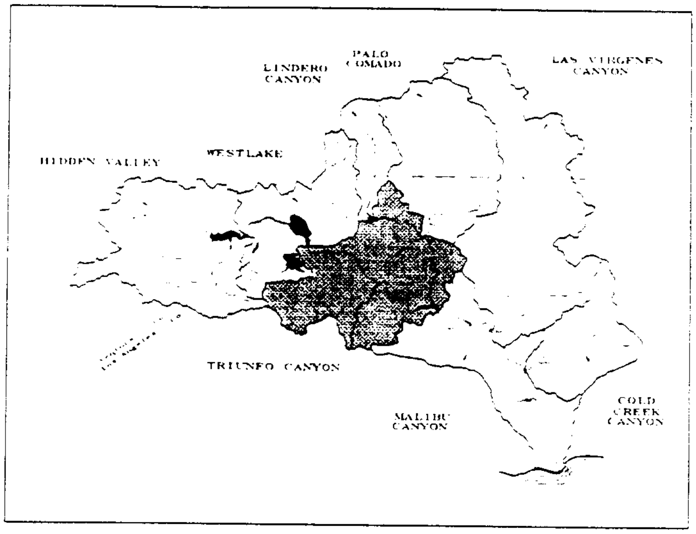
For Orchards, Lawns and Shrubs:
- Filter Strips
- Irrigation Water Management
- Nutrient Management

For Stormwater Runoff:
- Constructed Wetlands
- Filters
- Detention Basins

For Confined Animal Units:
- Waste Management Systems
- Waste Utilization
- Livestock Exclusion
- Fencing
- Pasture and Hayland Management

SUBWATERSHED OVERVIEW

The 11,349-acre Triunfo Canyon subwatershed contains 87 percent natural area, 9 percent residential area, 3 percent rural residential area, and 1 percent of the total area is comprised of confined animal units. Much of the residential area is located adjacent to Malibou Lake, which is the outlet of this subwatershed. The confined animal units appear to be concentrated along Triunfo Canyon and lower Medea Creek. There are 625 homes on septic systems in the subwatershed.



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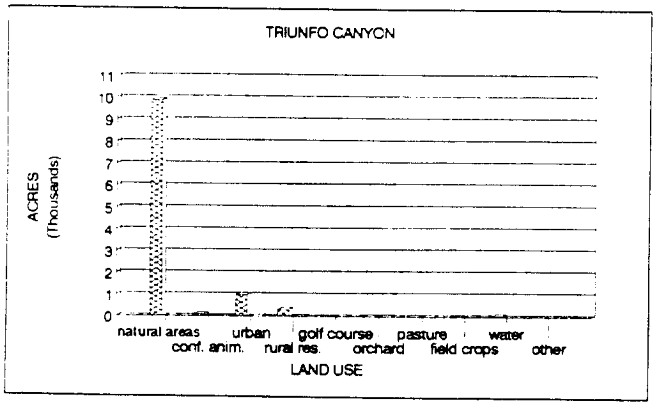


POTENTIAL TREATMENT

For Rural Land Uses:

- Access Road Improvements
- Critical Area Planting
- Sediment Basins
- Filter Strips
- Irrigation Water Management
- Nutrient Management

For Confined Animal Units:

- Waste Management Systems
- Waste Utilization
- Livestock Exclusion
- Pasture and Hayland Management
- Fencing
- Filter Strips

WATER QUALITY ISSUES

Major Water Bodies: Malibou Lake, Triunfo Creek, lower Medea Creek

Possible Concerns: Suspected sedimentation in Triunfo Creek, suspected eutrophication and sedimentation in Malibou Lake.

Possible Sources: Roads, streambanks, septic sysyems, confined animal units, fertilizers, runoff from upstream subwatershed

Designated Beneficial Uses:

Triufo Creek - Existing use - wildlife habitat; Intermittent uses - contact and noncontact water recreation*, warm freshwater habitat; Potential use - municipal and domestic supply

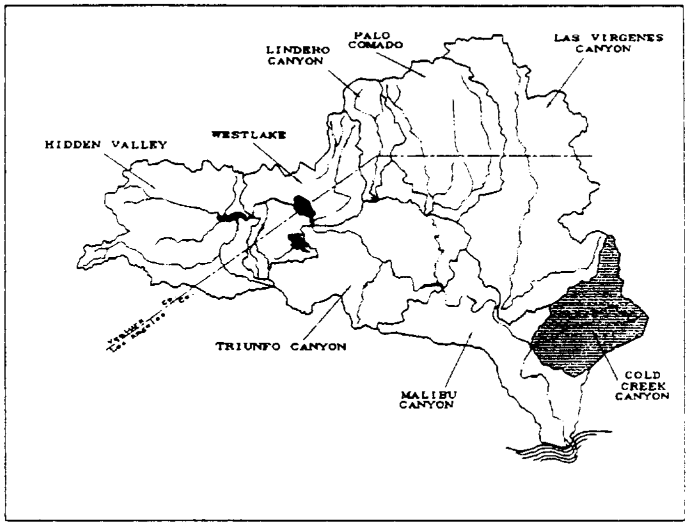
Malibou Lake: Existing uses - contact and noncontact water recreation*, warm freshwater habitat*, wildlife habitat, wetrlands habitat, rare and endangered species habitat*, navigation*; Potential use - municipal and domestic supply*

Lower Medea Creek: Existing uses - contact and noncontact water recreation, warm freshwater habitat, wildlife habitat, wetland habitat; Intermittent uses - municipal and domestic supply, groundwater recharge

* may be affected by the possible concerns

SUBWATERSHED OVERVIEW

The 5,235-acre Cold Creek subwatershed consists mostly of natural area with scattered rural residences on private septic systems and 34 acres of confined animal units concentrated in the lower portion of the subwatershed. The outlet of this subwatershed is the confluence of Cold and Malibu Creeks.



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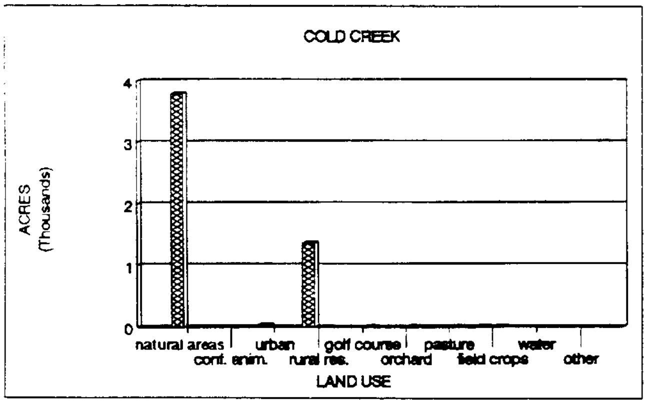


WATER QUALITY ISSUES

Major Water Body: Cold Creek

Possible Sources: Runoff from natural areas, wildlife wastes, septic systems, confined animal units, fertilizers

Designated Beneficial Uses: Existing uses - contact and non-contact water recreation*, warm freshwater habitat, cold freshwater habitat, wildlife habitat, mitigation, spawning, wetlands habitat, rare and endangered species habitat; Potential uses - municipal and domestic supply*

*may be affected by the possible concerns

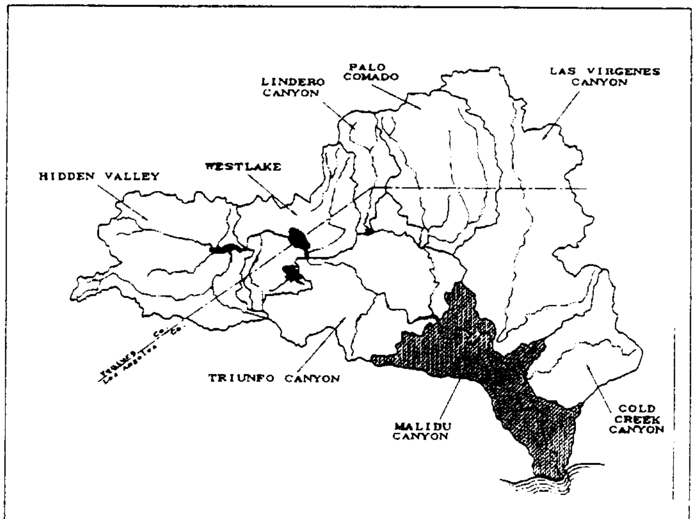
POTENTIAL TREATMENT

For Rural Land Uses:
- Filter Strips
- Irrigation Water Management
- Nutrient Management

For Confined Animal Units:
- Waste Management System
- Waste Utilization
- Waste Transfer
- Filter Strips
- Livestock Exclusion
- Pasture and Hayland Management
- Fencing

SUBWATERSHED OVERVIEW

The Malibu Creek subwatershed is the southernmost subwatershed for the Malibu Creek Watershed and ends at Malibu Lagoon by the City of Malibu. A full 93 percent of the subwatershed is natural area, with 3 percent rural residences and 2 percent urban area. There are also small acreages of confined animal units and golf courses. This subwatershed contains the Tapia Treatment Plant and Rindge Dam.



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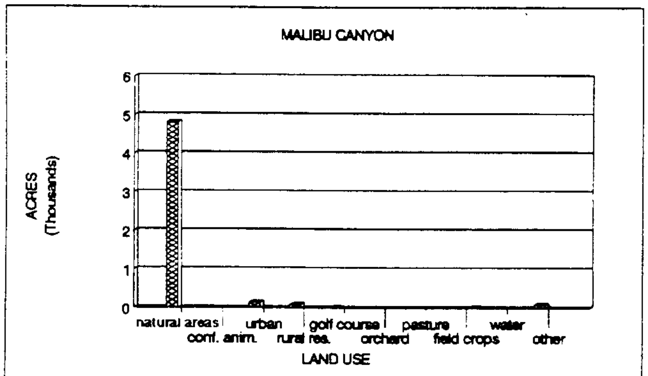

WATER QUALITY ISSUES

Major Water Bodies: Malibu Creek, Century Reservoir

Possible Concerns: High nutrient and bacteria levels, fish population decline, spawning impairment, and sedimentation

Possible Sources: Urban runoff, septic systems, wildlife, runoff from natural areas, fertilizers, confined animal units, erosion from roads

Designated Beneficial Uses: Existing uses - contact and non-contact water recreation*, warm freshwater habitat*, cold freshwater habitat*, wildlife habitat, migration*, spawning*, wetland habitat, rare and endangered species habitat: Potential uses - municipal and domestic supply*

* may be affected by possible concerns

POTENTIAL TREATMENT

For Rural Land Uses:
- Access Road Improvement
- Critical Area Planting
- Sediment Basin
- Filter Strip
- Irrigation Water Management
- Nutrient Management

For Confined Animal Units:
- Waste Management System
- Waste Utilization
- Waste Transfer
- Livestock Exclusion
- Fencing
- Filter Strip

For Stormwater Runoff:
- Filter Strips
- Detension Basins
- Constructed Wetlands

November 1997

R0026417

Compliments of the Resource Conservation District of the Santa Monica Mountains. For further information call 310-455-1030.

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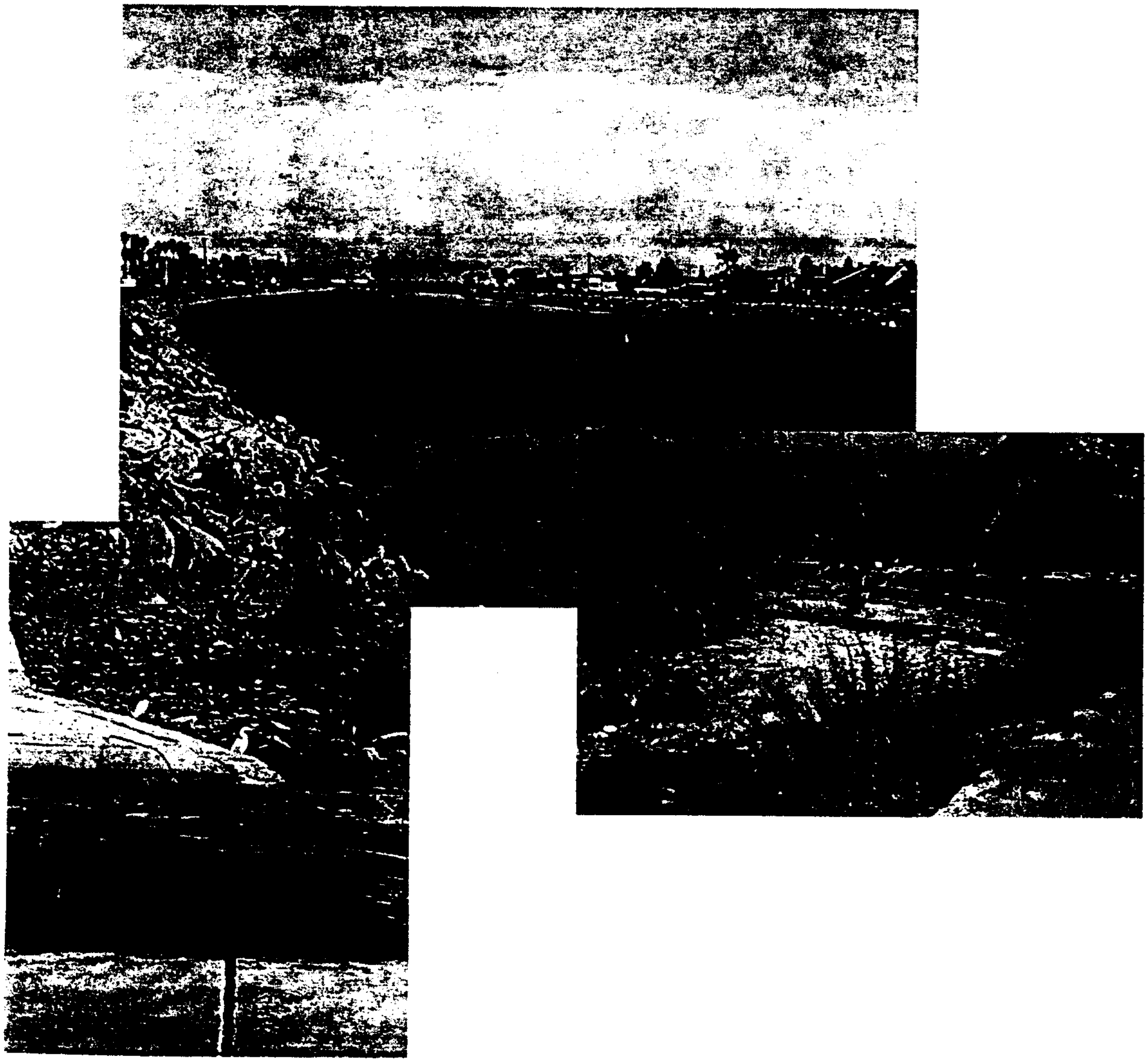
STATE OF THE WATERSHED – Report on Surface Water Quality

The San Gabriel River Watershed

June 2000



ADMINISTRATIVE RECORD
INDEX- DOCUMENTS-
WATER QUALITY, FOLDER 6
ITEM # 6

California Regional Water Quality Control Board

Los Angeles Region

Winston H. Hickox
Secretary for Environmental Protection

320 W. 4th Street, Suite 200, Los Angeles, CA 90013
Phone (213) 576-6600 FAX (213) 576-6640

Gray Davis
Governor

TO: San Gabriel River Watershed Stakeholders

FROM: Shirley Birosik
Watershed Coordinator
LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD

DATE: June 29, 2000

SUBJECT: SAN GABRIEL RIVER STATE OF THE WATERSHED REPORT

The San Gabriel River has been one of this year's targeted watersheds in our watershed management permitting cycle. As it represents a major watershed, we have prepared a State of the Watershed report for the river. A draft copy of this report was distributed in May for review and comments received on the draft report have been incorporated into this final document to the extent possible.

The emphasis of the report is on a broad look at data from a number of surface water sampling programs and general observations on surface water quality. Recommendations for more focused monitoring are made. An overview of the watershed and its infrastructure is also given. Although termed a "final report", the document will be updated at least every five years in line with our watershed permitting cycle.

The electronic version of the document contains a number of hyperlinks; some links are to websites and some are to Excel files containing data and charts. This hardcopy contains a limited number of these charts and none of the data from the spreadsheet files due to their very large size. These files may be obtained electronically from this office by contacting myself at 213-576-6679 or sbirosik@rb4.swrcb.ca.gov.

Enclosure

TABLE OF CONTENTS

Executive Summary ____ *i*

State of the Watershed ____ *1*

Physical Description of River, Tributaries, and Structures ____ 1

The Watershed's Designated Beneficial Uses ____ 4

Watershed Stakeholder Groups ____ 10

Water Resources, and Groundwater Agencies and Issues ____ 10

Discharges into the Watershed ____ 12

Current Water Quality Impairments ____ 16

Overview of Existing Monitoring Data ____ 18

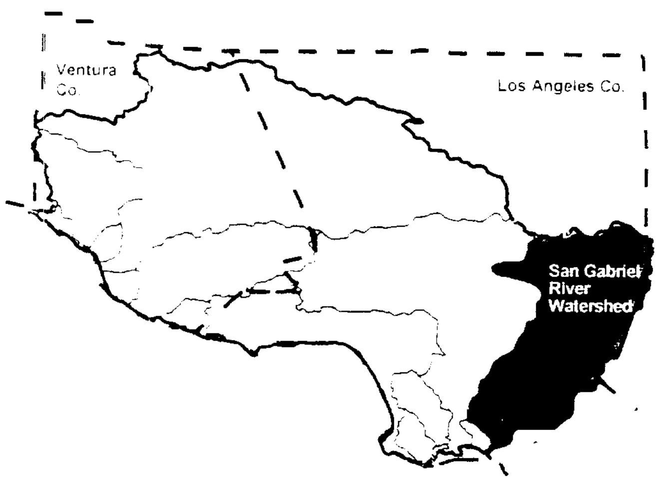
Recommendations for Future Monitoring ____ 23

Potential Long-term Activities ____ 24

References ____ *25*

Figures ____ *26*

Executive Summary



The San Gabriel River receives drainage from a 689 square mile area of eastern Los Angeles County; its headwaters originate in National Forest lands in the San Gabriel Mountains. The watershed consists of extensive areas of undisturbed riparian and woodland habitats in its upper reaches. Much of the watershed of the West Fork and East Fork of the river has been set aside by the U.S. Congress as a wilderness area; other areas (particularly the East Fork and lower North Fork)in the upper watershed are subject to heavy recreational use. The upper watershed also contains a series of flood control dams. Further downstream, toward the middle of the watershed, are large spreading grounds utilized for groundwater recharge. The watershed is hydraulically connected to the Los Angeles River through the Whittier Narrows Reservoir (occurring mostly during high storm flows). The lower part of the river flows through a concrete-lined channel in a heavily urbanized portion of the county before becoming an soft bottom channel once again near the ocean in the city of Long Beach. Large electrical power poles line the river along the channelized portion and nurseries, small stable areas, and a large poultry farm are located in these areas (CRWQCB-LA Region, 2000).

Water Quality Problems and Issues

Pollutants from dense clusters of residential and commercial land uses have impaired water quality in the middle and lower watershed. Tertiary-treated effluent from several sewage treatment plants enters the river in its middle reaches (which is partially channelized) while two power generating stations discharge cooling water into the river's estuary. The watershed is also covered under the municipal storm water NPDES permit. Several landfills are also located in the watershed.

Existing Beneficial Uses designated in the watershed:

Estuary	*Above Estuary (various reaches)*
Contact & noncontact water recreation	Contact & noncontact water recreation
Industrial service supply	Industrial service supply
Protection of rare & endangered species	Protection of rare & endangered species
Wildlife habitat	Wildlife habitat
Spawning	Spawning
Marine habitat	Warm- & coldwater habitat
Estuarine habitat	Municipal water supply
Navigation	Groundwater recharge
Commercial & sportfishing	Industrial process supply
Migratory	Agricultural supply

Significant Issues:

- Sluicing of reservoirs
- Protection of groundwater recharge areas
- Trash
- Watershed-wide monitoring
- Mining/stream, modifications
- Ambient toxicity
- Urban and storm water runoff quality
- Nonpoint source loadings from nurseries and horse stables
- Estuary dynamics
- Restoration of wetlands

Three reservoirs, which were constructed primarily for flood control purposes, occur in the upper part of the watershed. Frequent removal of accumulated sediments is necessary to maintain the flood control capacity of these reservoirs. Some of the removal methods previously used have had short-term water quality impacts. Continued need for such maintenance could cause longer-term impacts (CRWQCB-LA Region, 2000).

Permitted discharges:

- Nine major NPDES dischargers (five POTWs)
- 25 minor permits
- 39 discharges covered under general permits
- 536 dischargers covered under an industrial storm water permit
- 170 dischargers covered under a construction storm water permit

IMPAIRMENTS: The upper reaches of the river (in the Angeles National Forest) are heavily used for recreational purposes and have been impacted from trash (303(d)-listed as an impairment), debris, and habitat destruction. Various reaches of the river are on the 1998 303(d) list due to nitrogen and its effects, trash, PCBs and pesticides, metals, and coliform (CRWQCB-LA Region, 2000).

State of the Watershed

This document is primarily a report on surface water quality in the San Gabriel River Watershed. However, topics such as a physical description of the river and structures, water resources and related issues, groundwater agencies, and other broader topics are also included as needed. The reader may need to consult other documents for more detailed descriptions of habitats, wildlife, and structures than this document is meant to provide. This document will be updated in future watershed cycles.

Physical Description of River, Tributaries, and Structures

The San Gabriel River receives drainage from a 689 square mile area of eastern Los Angeles County and has a main channel length of approximately 58 miles; its headwaters originate in the San Gabriel Mountains with the East, West, and North Forks. The river empties to the Pacific Ocean at Los Angeles/ Orange Counties boundary in Long Beach. The main tributaries of the river are Big and Little Dalton Wash, San Dimas Wash, Walnut Creek, San Jose Creek, Fullerton Creek, and Coyote Creek (LA County DPW, 1994).

The Upper Watershed

The watershed consists of extensive areas of undisturbed riparian and woodland habitats in its upper reaches, much of which is set aside as a wilderness area by the U.S. Congress. Other areas in the upper watershed are subject to heavy recreational use. The upper watershed also contains a series of reservoirs with flood control dams (Cogswell, San Gabriel, and Morris Dams, going downstream) (CRWQCB-LA Region, 2000). Cogswell Dam (formerly San Gabriel Dam No. 2) is located 22 miles north of the city of Azusa on the West Fork of the San Gabriel River. Construction of the dam was begun in 1932 and was completed in 1934. Its primary purposes are flood control and water conservation and it drains an area of 39.2 square miles. San Gabriel Dam (formerly San Gabriel Dam No. 1) is located 7.5 miles north of the city of Azusa on the San Gabriel River. Construction of the dam was begun in 1932 and was completed in 1939. Its primary purposes are flood control and water conservation and it drains an area of 202.7 square miles. Morris Dam is located 5 miles north of the city of Azusa on the San Gabriel River. Construction of the dam was begun in 1932 and was completed in 1935. Its primary purpose is water conservation and it drains an area of 217 square miles (LA County DPW websites). There are a number of "beneficial uses" designated for these reservoirs (as well as all the waters of this watershed) by the CRWQCB-LA Region; see page 5 for further information.

Santa Fe Dam

The river flows out of the San Gabriel Canyon and into the San Gabriel Valley entering first the Santa Fe Dam and spreading grounds. Santa Fe Dam and Reservoir is a flood control project constructed under the authorization of the Flood Control Act of 1936 and operated by the U.S. Army Corps of Engineers, Los Angeles District. Construction of the project started in 1941and was completed in 1949 (USACE LA District, Reservoir Regulation Section website).

The project is located on the San Gabriel River about 4 miles downstream from the mouth of the San Gabriel Canyon. The Rio Hondo, a distributary of the San Gabriel River, branches from the river just below Santa Fe Dam and flows westward to Whittier Narrows Reservoir. From Whittier Narrows Reservoir, the San Gabriel River flows south to the Pacific Ocean, and the Rio Hondo flows southwestward to the Los Angeles River (USACE LA District, Reservoir Regulation Section website).

Santa Fe Dam is an element of the Los Angeles County Drainage Area (LACDA) flood control system. The primary purpose of Santa Fe Dam is to provide flood protection to downstream communities along the San Gabriel River between the Santa Fe Dam and Whittier Narrows Dam, and , in conjunction with the Whittier Narrows Dam, provide flood protection along the Rio Hondo Channel, the Los Angeles River, and the San Gabriel River.. The second authorized purpose of the Santa Fe Dam is to provide recreation opportunities. The Santa Fe basin also includes a Wildlife Management Area, a designated sensitive habitat area. The flood control operation of Santa Fe Dam is also coordinated with the operation of other Corps dams in the LACDA system, namely Whittier Narrows Dam, Hansen Dam and Sepulveda Dam.

Although it has no authorized storage allocation for water supply, its flood control operation provides incidental water conservation benefits to the people of San Gabriel Valley and other parts of the Los Angeles Basin (USACE LA District, Reservoir Regulation Section website and USACE LA District, 1998).

Santa Fe Dam contains sixteen hydraulically operated gates set to pass low flows and build a debris pool during high inflows. Discharge rates within the debris pool range allows the Los Angeles County Department of Public Works to divert the flow to its spreading facilities, thereby enhancing water conservation. Once the reservoir level reaches elevation 456 feet, flood control releases are initiated and the flood pool is drained as rapidly as possible, consistent with the achievement of downstream flood control. As soon as the flood pool is drained, releases are reduced so that LACDPW can resume water conservation operation. (USACE LA District, Reservoir Regulation Section website).

The LACDPW has operated and maintained the Santa Fe Reservoir Spreading Grounds (SFRSG) since 1953 through an easement with the USACE. Stormwater and imported water diverted from the San Gabriel River are spread in the area. The spreading grounds are east and west of the San Gabriel River and occupy the northwest portion of the Santa Fe Reservoir. The SFRSG receives controlled releases from Morris Dam; also receives seasonal local flows originating in San Gabriel Canyon and imported water releases from the Upper San Gabriel Valley Municipal Water District's USG-3 outlet and from the San Gabriel Valley Municipal Water District's outlet to Beatty Channel (USACE - LA County DPW/Water Conservation Division, 1995).

The spreading grounds recharge water to the Main San Gabriel Basin underlying the San Gabriel Valley. The basin has an estimated storage capacity of 9.5 million acre-feet and is bounded by the San Gabriel Mountains on the north, the Puente Hills on the south, the San Jose Hills to the east, and the San Rafael Hills to the west. The Santa Fe Dam Recreation Area is located approximately one mile southeast of the SFRSG (USACE - LA County DPW/Water Conservation Division, 1995).

The Santa Fe Dam Floodplain has been designated as a LA County Significant Ecological Area (SEA No. 22) as defined by the County Zoning Code. This area has been designated as a Class 3 (5,7) SEA. Class 3 designates an area where the biotic communities, vegetative associations, and habitat of plant and animal species that are either one of a kind or restricted in distribution in LA County. Class 5 designates an area that contains biotic resources that are of scientific interest because they are either an extreme in physical/geographical limitations or they represent an unusual variation in a population or community. Class 7 designates areas that would provide for the preservation of relatively undisturbed examples of the natural biotic communities in LA County. The extensive alluvial fan sage scrub, lowland riparian, and freshwater marsh habitats located in the flood control basin are the major resources supporting the SEA designation (USACE - LA County DPW/Water Conservation Division, 1995).

The Area Between Santa Fe and Whittier Narrows Dams

The San Gabriel River Channel between Santa Fe Dam and the Whittier Narrows Basin is soft-bottomed with riprap sides. LACDPW has constructed a rubber dam in the San Gabriel River channel just downstream of the Walnut Creek confluence which can impound up to 400 AF (USACE LA District, 1998).

Walnut Creek is a tributary to the San Gabriel River above the Whittier Narrows area. Puddingstone Reservoir is located on upper Walnut Creek and is operated for flood control, water conservation, and recreation with a relatively small flood control allocation (USACE LA District, 1998).

San Jose Creek, a soft-bottomed channel, also enters the San Gabriel River upstream of the Whittier Narrows area, but downstream of the Walnut Creek confluence and its dry-weather flow is dominated by tertiary-treated effluent from a nearby treatment plant.

Whittier Narrows Dam

Whittier Narrows Dam is a flood control and water conservation project constructed and operated by the USACE, Los Angeles District. Construction of the project was completed in 1957. The Whittier Narrows are a natural gap in the hills that form the southern boundary of the San Gabriel Valley. The Rio Hondo and the San Gabriel River flow through this gap and are impounded by the reservoir (USACE LA District, Reservoir Regulation Section website).

The purpose of the project is to collect runoff from upstream along with releases into the San Gabriel River from Santa Fe Dam, thus, the primary authorized purpose of Whittier Narrows Dam is flood control. Subsequent Acts of Congress authorized the development of the area for park and recreational purposes. There is also a nature area located in the southeast area of the basin which was developed as mitigation for the established recreation facilities. The third authorized purpose of water conservation was granted in 1956 (USACE LA District, Reservoir Regulation Section website and USACE LA District, 1998).

If the inflow to the reservoir exceeds the groundwater recharge capacity of the spreading grounds along the Rio Hondo or the bed of the San Gabriel River downstream, this water is stored temporarily in a water conservation pool. The Rio Hondo and San Gabriel sides of the reservoir each have their own water conservation pools. If the water conservation pool on the Rio Hondo side is exceeded, flows are released into the Rio Hondo at a rate which does not exceed the downstream channel capacity of either the Rio Hondo or the LA River. If the water conservation pool on either side of the reservoir is exceeded a release of approximately 5,000 cfs can be made into the San Gabriel River. If the pool in the reservoir exceeds flood control storage, the gates on the San Gabriel River outlet begin to open automatically and emergency releases are made into the river (USACE LA District, Reservoir Regulation Section website).

The gates on the Rio Hondo outlet are normally wide open. On the San Gabriel side one gate is normally open about 0.5 feet with the remaining gates closed. The reservoir is normally empty and a weir within the reservoir keeps the flows from the Rio Hondo and the San Gabriel River separated. The natural flow to each river therefore normally passes through the dam unhindered. During the initial stages of a flood event, the gates on the Rio Hondo side are partially closed to build a water conservation pool. As long as the pool on the Rio Hondo side of the reservoir is below a certain elevation, releases are made to accommodate the capacity of the spreading grounds downstream along the Rio Hondo. All outflow to the San Gabriel River from Whittier Narrows Dam is through or over the spillway gates. Whittier Narrows currently provides greater than 100-year protection to areas downstream from the spillway on the San Gabriel River. There are plans to retain more water behind both Santa Fe and Whittier Narrows Dams, and in turn increase downstream water recharge, through increasing the size of the pools behind the dams and releasing water at a slower rate (USACE LA District, Reservoir Regulation Section website and USACE LA District, 1998).

Potentially occurring federal and state listed and candidate species in the riparian habitat of the Whittier Narrows Dam area include Least Bell's Vireo (federal and state listed) and tricolored blackbird (California species of special concern and a candidate for federal listing). The California gnatcatcher potentially occurs in the coastal sage scrub of the dam area and is a California species of special concern and federal threatened species (LA County DPW, 1994).

Recharge Areas Below Whittier Narrows

Further downstream, along the Rio Hondo and San Gabriel River, are large spreading grounds utilized for groundwater recharge. The stretch of the river below the Whittier Narrows area overlies the Central Basin groundwater basin which contains a number of shallow aquifers and three deeper aquifers (the Silverado, the Sunnyside, and the Lynwood). The deep and shallow aquifers are recharged by underflow through the Whittier Narrows from the north, and by percolation from the San Gabriel River and the Rio Hondo Channel, which flows into the Montebello Forebay just south of the Narrows. This surface and subsurface flow through the Narrows represents outflow from the upstream San Gabriel Basin. The San Gabriel River and Rio Hondo are unlined in this area, allowing for groundwater recharge at the San Gabriel Coastal Basin Spreading Grounds and the Rio Hondo Spreading Grounds, respectively (LA County DPW, 1994).

The Montebello Forebay is a recharge facility located immediately downstream of Whittier Narrows Dam and allows infiltration into the Central Basin aquifer. The Rio Hondo Coastal Basin Spreading Grounds are located on the banks of the Rio Hondo south of Whittier Boulevard, 2 miles downstream from the Whittier Narrows Dam. The spreading grounds are owned and operated by the LACDPW which uses gates across the Rio Hondo to divert flow to three separate intake structures. The San Gabriel River Coastal Spreading Basins are operated by the LACDPW. They are located on the west side of the San Gabriel River between Whittier Boulevard and Washington Boulevard. Water is diverted to the grounds by way of two rubber dams across the soft-bottomed river channel (USACE LA District, 1998).

Up to an annual average of 50,000 AF per year of reclaimed water is used to supplement local surface water and imported water for replenishing the Central Basin aquifer through the Montebello Forebay. The source of reclaimed water is from the following three water reclamation plants owned and operated by the County Sanitation Districts of Los Angeles County (CSDLAC): Whittier Narrows, San Jose Creek, and Pomona (CSDLAC, 2000).

The Lower Watershed

The lower part of the river flows through a concrete-lined channel in a heavily urbanized portion of the county before becoming an soft bottom channel once again near the ocean in the city of Long Beach. The concrete-lined Coyote Creek joins the San Gabriel River at the tidal prism in Long Beach south of Willow Street (CRWQCB-LA Region, 2000).

The Alamitos Barrier is an engineered freshwater pressure ridge and seawater trough located in the City of Long Beach. The Barrier is designed to protect the Central Groundwater Basin of Los Angeles County and the Orange County Groundwater Basin (which are geologically one basin) from seawater intrusion through an alluvium-filled erosional gap, commonly known as the Alamitos Gap. Currently, the Barrier is maintained through the injection of treated, imported potable water. The seawater trough is created by the extraction of brackish groundwater from four wells located on the seaward side of the injection well arc, and barrier performance is monitored through observations conducted at 230 wells located at multiple sites near the gap (Water Replenishment District of Southern California, 1998).

The combination of wells is designed to reverse the inland gradient of subsurface water and thus prevent further seaward intrusion. The Central Basin Municipal Water District supplies imported water to the Water Replenishment District of Southern California for groundwater replenishment and barrier injection (Water Replenishment District of Southern California, 1998).

The Watershed's Designated Beneficial Uses

The Los Angeles Regional Board's Basin Plan is designed to preserve and enhance water quality and protect the beneficial uses of all regional waters. Beneficial uses form the cornerstone of water quality protection. Once beneficial uses are designated, appropriate water quality objectives can be established and programs that maintain or enhance water quality can be implemented to ensure the protection of beneficial uses. The designated beneficial uses, together with water quality objectives, form water quality standards. Such standards are mandated for all waterbodies within the state under the California Water Code. In addition, the federal Clean Water Act mandates standards for all surface waters, including wetlands (CRWQCB-LA Region, 1994).

There are twenty-four beneficial uses in the Region as a whole; examples include wildlife habitat, municipal water supply, navigation, and marine habitat. These uses and their definitions were developed by the State and Regional Boards for use in the Regional Board Basin Plans. Beneficial uses can be designated for a waterbody in a number of ways. Those uses that have been attained for a waterbody on, or after, November 28, 1975, must be designated as "existing" in the Basin Plans. Other uses can be designated, whether or not they have been attained in a waterbody, in order to implement either federal or state mandates and goals (such as fishable and swimmable) for regional waters. Beneficial uses of streams that have intermittent flows, which can support some beneficial uses during dry periods through shallow ground water or small pools, are designated as intermittent. In addition, a use can be designated as "potential" if there are plans or potential to put the water to such future use among other reasons (CRWQCB-LA Region, 1994).

The beneficial uses of the San Gabriel River and its tributaries are listed in the table below as they appear in the Los Angeles Regional Board's Basin Plan

Waterbody[a]	Hydro Unit #	MUN	IND	PROC	AGR	GWR	FRSH	NAV	POW	REC1	REC2	COM	AQUA	WARM	COLD	SAL	EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	SHELL	WET[b]
SAN GABRIEL RIVER WATERSHED																									
San Gabriel River Estuary c,w	405.15		E					E		E	E	E					E	E	E		Ee	Ef	Ef	P	
San Gabriel River Firestone Blvd Estuary	405.15	P*								Em	E			P					P						
San Gabriel River Whittier N-Firestone	405.15	P*	P	P		I				Em	E			I					E		E				
San Gabriel River	405.41	P*				I				Im	I			I					E						
San Gabriel River	405.42	E	E	E	E	E				E	E			E	E				E		E				
San Gabriel River. Main Stem z	405.43	E	E	E	E	E				E	E			E	E				E				E		
North Fork San Gabriel River	405.43																								
West Fork San Gabriel River	405.43																								
East Fork San Gabriel River	405.43																								
Coyote Creek to Estuary	405.15	P*	P	P						Pm	I			P					P		E				
Whittier Narrows Flood Control Basin	405.41	P*				E				E	E			E					E		P				
Legg Lake	405.41	P*				E				E	E			E	E				E						E
San Jose Creek	405.41	P*				I				Pm	I			I					E						
San Jose Creek	405.51	P*				I				Pm	I			I					E						
Puente Creek	405.41	P*				I				P	I			P					P						
Thompson Wash	405 52	P*				I				Im	I			I					E						
Thompson Creek	405.53	P*				I				I	I			I					E		E				
Thompson Creek Dam & Reservoir	405.53	P*				I				Px	I			I					E		E				
Walnut Creek Wash	405.41	P*				I				Im	I			I					E						E
Big Dalton Wash	405.41	P*				I				Pm	I			P					P						
Big Dalton Canyon Creek	405.41	P*				I				I	I			I					E						E
Mystic Canyon	405.41	P*				I				I	I			I					E						
Big Dalton Dam & Reservoir	405.41	P*				E				Px	E			E					E						
Bell Canyon Creek	405.41	P*				I				I	I			I					E						
Little Dalton Wash	405.41	P*				I				Pm	I			P					P						
Little Dalton Canyon Creek	405.41	P*				I				I	I			I					E						E

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E: Existing beneficial use
P: Potential beneficial use
I: Intermittent beneficial use
E, P, and I shall be protected as required
* Asterixed MUN designations are designated under SB 88-63 and RB 89-03. Some designations may still be considered for exemptions at a later date.

Footnotes are consistent on all beneficial use tables.

a Waterbodies are listed multiple times if they cross hydrologic area or sub area boundaries. Beneficial use designations apply to all tributaries to the indicated waterbody, if not listed separately.
b Waterbodies designated as WET may have wetlands habitat associated with only a portion of the waterbody. Any regulatory action would require a detailed analysis of the area.
c Coastal waterbodies which are also listed in Coastal Features Table (2-3) or in Wetlands Table (2-4).
e One or more rare species utilize all ocean, bays, estuaries, and coastal wetlands for foraging and/or nesting.
f Aquatic organisms utilize all bays, estuaries, lagoons and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater inputs.

k Public access to reservoir and its surrounding watershed is prohibited by the Los Angeles Department of Water and Power.
m Access prohibited by Los Angeles County DPW in concrete-channelized areas.
s Access prohibited by Los Angeles County DPW.
v Public water supply reservoir. Owner prohibits public entry.
w These areas are engineered channels. All references to Tidal Prisms in Regional Board documents are functionally equivalent to estuaries.
x Owner prohibits entry.

Waterbody[a]	Hydro Unit #	MUN	IND	PROC	AGR	GWR	FRSH	NAV	POW	REC1	REC2	COM	AQUA	WARM	COLD	SAL	EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	SHELL	WET[b]
San Dimas Wash (lower)	405.41	P*				I				Im	I			I					E		E				
San Dimas Wash (upper)	405.44	P*				E				Im	I			I					E						
San Dimas Dam and Reservoir	405.44	E*				E				Px	E			E	E				E						
San Dimas Canyon Creek	405.44	E*				E				E	E			E	E				E						E
West Fork San Dimas Canyon	405.44	E*				E				E	E			E	P				E						E
Wolfskill Canyon	405.44	E*				E				E	E			E	P				E		E				E
Puddingstone Dam and Reservoir	405.52	E*			E	E				E	E			E	E				E		E				
Puddingstone Wash	405.41	E*				I				Im	I			I					E						
Marshall Creek and Wash	405.41	E*				I				Im	I			I					E						
Marshall Creek and Wash	405.53	E*				I	I			Im	I			I					E		E				E
Live Oak Wash	405.52	E*				I	I			I	I			I					E						
Live Oak Creek and Wash	405.53	E*				I	I			I	I			I					E						
Live Oak Dam and Reservoir	405.53	E*				E	E			E	E			E					E						
Emerald Creek and Wash	405.53	E*				I	I			Im	I			I					E						
Santa Fe Flood Control Basin	405.41	P*				I				P	I			I					E						E
Bradbury Canyon Creek	405.41	P*				I				I	I			I					E						
Spinks Canyon Creek	405.41	P*				I				I	I			I					E						
Maddock Canyon Creek	405.43	P*				I				I	I			I					E						
Van Tassel Canyon	405.43	P*				I				I	I			I					E		E				
Fish Canyon Creek	405.43	P*				E				E	E			E					E		E		E		E
Roberts Canyon Creek	405.43	P*				I				I	I			I					E		E				E
Morris Reservoir	405.43	E	E	E	E	E			E	P	E			E	E				E				E		
San Gabriel Reservoir	405.43	E	E	E	E	E			E	E	E			E	E				E						
UPPER SAN GABRIEL RIVER TRIBUTARIES																									
San Gabriel River: Main Stem z	405.43	E	E	E	E	E				E	E			E	E				E						E
Cattle Canyon Creek	405.43	P*				E				E	E			E	E				E		E		E		E
Coldwater Canyon Creek	405.43	P*				E				E	E			E	E				E		E		E		E
Cow Canyon Creek	405.43	P*				E				E	E			E	E				E		E		E		E
East Fork San Gabriel River	405.43	P*				E				E	E			E	E				E		E		E		E
Allison Gulch	405.43	P*				E				E	E			E	E				E				E		E
Fish Fork	405.43	P*				E				E	E			E	E				E				E		E

E. Existing beneficial use
P. Potential beneficial use
I Intermittent beneficial use
E, P, and I shall be protected as required
* Asterixed MUN designations are designated under SB 88-63 and RB 89-03. Some designations may still be considered for exemptions at a later date.

Footnotes are consistent on all beneficial use tables.

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w These areas are engineered channels. All references to Tidal Prisms in Regional Board documents are functionally equivalent to estuaries.
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Waterbody[a]	Hydro Unit #	MUN	IND	PROC	AGR	GWR	FRSH	NAV	POW	REC1	REC2	COM	AQUA	WARM	COLD	SAL	EST	MAR	WILD	BIOL	RARE	MIGR	SPWN	SHELL	WET[b]
North Fork San Gabriel River	405.43	P*				E				E	E			E	E				E		E		E		E
Bichota Canyon	405.43	P*				E				E	E			E	E				E		P		E		
Coldbrook Creek	405.43	P*				I				I	I			I					E				E		
Cedar Creek	405.43	P*				E				E	E			E	E				E		E		E		E
Crystal Lake	405.43	P*								E	E			E	E				E				E		
Soldier Creek	405.43	P*				I				I	I			I					E				E		
West Fork San Gabriel River	405.43	P*				E				E	E			E	E				E		E		E		E
Bear Creek	405.43	P*				E				E	E			E	E				E		E		E		E
Cogswell Reservoir	405.43	P*				E				E	E			E	E				E				E		E
Devils Canyon Creek	405.43	P*				E				E	E			E	E				E				E		E

E: Existing beneficial use

P: Potential beneficial use
I: Intermittent beneficial use
E, P, and I shall be protected as required
* Asterixed MUN designations are designated under SB 88-63 and RB 89-03. Some designations may still be considered for exemptions at a later date.

Footnotes are consistent on all beneficial use tables.

a Waterbodies are listed multiple times if they cross hydrologic area or sub area boundaries. Beneficial use designations apply to all tributaries to the indicated waterbody, if not listed separately.
b Waterbodies designated as WET may have wetlands habitat associated with only a portion of the waterbody. Any regulatory action would require a detailed analysis of the area.
c Coastal waterbodies which are also listed in Coastal Features Table (2-3) or in Wetlands Table (2-4).
e One or more rare species utilize all ocean, bays, estuaries, and coastal wetlands for foraging and/or nesting.
f Aquatic organisms utilize all bays, estuaries, lagoons and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater inputs.

k Public access to reservoir and its surrounding watershed is prohibited by the Los Angeles Department of Water and Power

m Access prohibited by Los Angeles County DPW in concrete-channelized areas.
s Access prohibited by Los Angeles County DPW.
v Public water supply reservoir. Owner prohibits public entry.
w These areas are engineered channels. All references to Tidal Prisms in Regional Board documents are functionally equivalent to estuaries.
x Owner prohibits entry.

Beneficial Use Definitions

Beneficial uses for waterbodies in the Los Angeles Region are listed and defined below. The uses are listed in no preferential order.

Municipal and Domestic Supply (MUN)
Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Agricultural Supply (AGR)
Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Industrial Process Supply (PROC)
Uses of water for industrial activities that depend primarily on water quality.

Industrial Service Supply (IND)
Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.

Ground Water Recharge (GWR)
Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Freshwater Replenishment (FRSH)
Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

Navigation (NAV)
Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

Hydropower Generation (POW)
Uses of water for hydropower generation.

Water Contact Recreation (REC-1)
Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

Non-contact Water Recreation (REC-2)
Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Commercial and Sport Fishing (COMM)
Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Aquaculture (AQUA)
Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Warm Freshwater Habitat (WARM)
Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold Freshwater Habitat (COLD)
Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Inland Saline Water Habitat (SAL)
Uses of water that support inland saline water ecosystems including, but not limited to, preservation or enhancement of aquatic saline habitats, vegetation, fish, or wildlife, including invertebrates.

Estuarine Habitat (EST)
Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Wetland Habitat (WET)
Uses of water that support wetland ecosystems, including, but not limited to, preservation or enhancement of wetland habitats, vegetation, fish, shellfish, or wildlife, and other unique wetland functions which enhance water quality, such as providing flood and erosion control, stream bank stabilization, and filtration and purification of naturally occurring contaminants.

Marine Habitat (MAR)
Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

Wildlife Habitat (WILD)
Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Preservation of Biological Habitats (BIOL)
Uses of water that support designated areas or habitats, such as **Areas of Special Biological Significance (ASBS),** established refuges, parks, sanctuaries, ecological reserves, or other areas where the preservation or enhancement of natural resources requires special protection.

Watershed Stakeholder Groups

Los Angeles/San Gabriel Rivers Watershed Council: This group was formed in 1995 following a large watershed conference held in the area which served to encourage other efforts. The Council has a board of directors and became incorporated as a nonprofit organization in 1996. The group is tracking watershed activities, but has primarily focused on flood control issues in the Los Angeles River as well as opportunities to create greenbelts and restore habitat. The Council's goal is to help facilitate a process to preserve, restore, and enhance all aspects of the double watershed. Currently, the Watershed council is heading up the Los Angeles County Task Force of the Southern California Wetlands Recovery Project. The Council is also initiating a Watershed Management Plan for both the Los Angeles and San Gabriel River. Their website is at http://lasgriverswatershed.org/.

Friends of the Los Angeles River: Friends of the Los Angeles River is a non-profit organization founded in 1986 to protect and restore the natural and historic heritage of the Los Angeles River and its riparian habitat through inclusive planning, education, and stewardship. Their website is at http://www.folar.org/.

Water Resources, and Groundwater Agencies and Issues

Groundwater in certain areas of the San Gabriel Basin has been impacted by volatile organics attributable to widespread industrial land use and associated contaminant releases over the last several decades. In

1979, VOCs were discovered in a number of public water supply wells in the San Gabriel Basin. As a result, the USEPA and the Regional Board entered into a cooperative agreement in 1989 to identify and cleanup the contamination. Subsequent investigations revealed more widespread soil and groundwater contamination in the Basin. During the last 15 years, more than one quarter of the approximately 366 water supply wells in the San Gabriel Valley has been found to be contaminated. The Regional Board, under authority of the California Water Code, locates and abates the sources of pollutants affecting these wells and oversees the remediation of the pollution. These investigations, conducted through the Well Investigation Program (WIP), are designed to identify and eliminate sources of pollutants in public water supply wells; identify dischargers by establishing a cause-and-effect relationship between the discharge of a pollutant and a polluted well; when necessary, take enforcement action against dischargers in order to force them to undertake site investigations and corrective actions; and oversee remediation of soils.

Soil and groundwater in the San Gabriel Valley are contaminated by volatile organic compounds such as PCE, TCE, and 1,1,1-TCA. Since 1997, new chemicals called emerging chemicals have been found in drinking water and groundwater monitoring wells. These chemicals include perchlorate, NDMA, and 1,4-dioxane which are carcinogens or suspected carcinogens.

The Regional Board has been the lead agency that oversees soil cleanup and "hot spot" groundwater cleanup. These are sites where groundwater contamination is so significant it warrants site-specific cleanup. USEPA is the lead agency for the regional groundwater cleanup. The various operable units (Superfund areas) in the Valley, such as Baldwin Park, Whittier Narrows, Puente Valley, El Monte, South El Monte, and Alhambra are at various stages of site assessment and cleanup.

Although the main goal of hot spot cleanups is the removal of high levels of contaminants, responsible parties are encouraged to reduce their cleanup costs by either sharing soil and/or groundwater treatment systems or reusing treated groundwater in their processes (CRWQCB – LA Region website).

Agencies with a vested interest in water resources in southern California:

- **Los Angeles County Department of Public Works** – The Los Angeles County Flood Control District was created in 1915 by the State legislature with the charge to control and conserve flood, storm, and other wastewaters. Since 1985 the LACDPW has been performing the functions of the flood control district. Under its conservation mission, LACDPW owns or operates 29 water spreading areas where groundwater is recharged. Several dams and reservoirs, including the U.S. Army Corps Whittier Narrows Dam, are operated to store water for post storm releases to downstream spreading grounds.
- **Metropolitan Water District of Southern California** – The MWD is a public agency and quasi-municipal corporation. Currently the MWD imports water from two sources, the Colorado River via the Colorado River Aqueduct and Northern California via the State Water project and its California Aqueduct.. MWD's primary purpose is to develop, store, and distributed water at wholesale rates to its member agencies. MWD is composed of 27 member agencies, including 14 cities, 12 municipal water districts, and one county water authority.
- **Department of Water and Power, City of Los Angeles** – The DWP imports water from the Owens Valley and Mono Basin through the Los Angeles Aqueducts. The remainder of the City's needs are supplied by local groundwater supplies and imported water from the MWD.
- **Water Replenishment District of Southern California** – The primary objectives of the WRD are to provide high quality water to its users, minimize adverse effects produced by years of groundwater pumping, and to oversee groundwater recharge operations in the Central and West Coast Basins. WRD purchases water imported through the State Water Project or the Colorado River Project and reclaimed water from CSDLAC to supplement storm runoff to replenish the groundwater basins. Direct groundwater recharge is accomplished through percolation at the spreading grounds adjacent to the Rio Hondo and the San Gabriel River; further replenishment is accomplished by injecting water at three freshwater barriers (West Coast Basin, Dominguez Gap, and Alamitos Barriers).
- **County Sanitation Districts of Los Angeles County** – The CSDLAC is a supplier of reclaimed water used during groundwater replenishment. Effluent from its facilities is a major part of the surface flow in the river during dry weather.
- **San Gabriel Valley Municipal Water District** – The District is composed of four cities and imports water to the San Gabriel Basin via the East Branch of the State Water Project.

- **West Basin and Central Basin Municipal Water Districts** – The West basin and Central Basin provide service to more than 40 cities and distribute wholesale water to approximately 50 separate water utilities. The Districts are involved in water conservation programs, water quality improvement projects, recycled water projects, and brackish groundwater desalting.
- **Upper San Gabriel Valley Municipal Water District** – The District was incorporated in 1960 by popular referendum and was annexed to the MWD in 1963. The District was formed to help solve water supply problems of the rapidly developing San Gabriel Valley.
- **Three Valleys Municipal Water District** – The Distract was formed in 1950 by popular referendum and was annexed to the MWD later in 1950. The District was formed to [provide supplemental imported water to serve growing needs of orchards and communities in the Pomona, Walnut, and eastern San Gabriel Valleys (LA County DPW, 1994).

Discharges into the Watershed

Major Dischargers

The Joint Outfall System (JOS) is the CSDLAC's integrated network of facilities which includes seven treatment plants, five of which are associated with the San Gabriel River Watershed. These five treatment plants (Whittier Narrows, Pomona, Long Beach, Los Coyotes, and San Jose Creek) are connected to the Joint Water Pollution Control Plant (JWPCP) which discharge off of the Palos Verdes Peninsula. This system allows for the diversion of desired flows into or around each "upstream" plant. Sludge (sewage solids separated from the wastewaters) from the upstream plants are returned to the trunk sewer for treatment at JWPCP (CRWQCB – LA Region files).

The Whittier Narrows Water Reclamation Plant is located within the Whittier Narrows basin on the west side of Rosemead Boulevard, between the Pomona Freeway and San Gabriel Boulevard. The facility discharges 10 MGD of tertiary-treated water into the Rio Hondo for groundwater recharge in downstream spreading grounds. Some reclaimed water is used to irrigate a nearby commercial nursery. The plant is constructed to be fully functional during flood events (USACE, LA District, 1998). Discharges from this facility normally are diverted to the Rio Hondo Spreading Grounds for groundwater replenishment. However, during heavy storm runoff, the effluent will enter the Los Angeles River through the Rio Hondo; there are times when discharges may enter the San Gabriel River depending on the depth of water behind the dam.

Two other water reclamation plants, the Pomona and San Jose Creek Water Reclamation Plants, discharge water into the middle reaches of the San Gabriel River. The Pomona plant discharges about 2.5 MGD to San Jose Creek which flows into the Whittier Narrows basin via the San Gabriel River. The San Jose Creek plant has three outlets to the river, one to San Jose Creek, one to the unlined portion of the San Gabriel River upstream of the San Gabriel River Coastal Spreading Grounds, and one outlet to the lined portion of the river downstream of the spreading grounds (USACE, LA District, 1998). The Los Coyotes and Long Beach Water Reclamation Plants discharge into the lower watershed.

In addition, two generating stations discharge into the tidal prism just north of Second St. (Westminster Ave.), the Haynes and Alamitos Generating Stations. Both draw in water from the nearby Los Cerritos Watershed Management Area.

<u>POTWs</u> (California Regional Water Quality Control Board – Los Angeles Region files)

County Sanitation Districts of Los Angeles County, Los Coyotes Water Reclamation Plant (Los Coyotes WRP) Order No. 95-077, CA0054011

- Located at 16515 Piuma Avenue, Cerritos
- Design capacity of 37.5 MGD
- Treatment is primary sedimentation, activated sludge biological treatment, secondary sedimentation, coagulation, inert media filtration, chlorination, dechlorination
- Tertiary-treated municipal and industrial wastewater is discharged into the San Gabriel River 1,230 feet upstream of the Artesia Freeway, above the estuary

- A portion of the treated effluent is reclaimed for landscape irrigation and is regulated under Order No. 87-51.

County Sanitation Districts of Los Angeles County, San Jose Creek Water Reclamation Plant (San Jose Creek WRP) Order No. 95-079, CA0053911

- Located at 1965 South Workman Mill Road, Whittier
- Design capacity of 100 MGD
- Treatment is primary sedimentation, activated sludge biological treatment, secondary sedimentation, coagulation, inert media filtration, chlorination, dechlorination
- Tertiary-treated municipal and industrial wastewater is discharged via three discharge points:
    - Discharge No. 001 to the San Gabriel River is the primary discharge outfall which is eight miles south of the plant near Firestone Blvd. From this point treated effluent flows directly to a concrete-lined, low flow channel in the river and travels about nine miles prior to reaching the estuary.
    - Discharge No. 002 to San Jose Creek is used for groundwater recharge at Rio Hondo and the San Gabriel Coastal Spreading Grounds. San Jose Creek is unlined from the discharge point to the San Gabriel River.
    - Discharge No. 003 delivers treated effluent to the unlined portion of the San Gabriel River as well as both the Rio Hondo and San Gabriel Coastal Spreading Grounds for groundwater replenishment.
- In addition to groundwater recharge, a portion of the treated effluent is used for irrigation and industrial process water and is regulated under Order No. 87-50. Treated effluent for groundwater recharge and discharged to lined channels is partially dechlorinated; that used for direct reuse is not dechlorinated. The discharge to the lined channel (No. 001) leaves the treatment plant at about 1 mg/l residual chlorine and is less than 0.1 mg/l upon discharge to the lined portion of the San Gabriel River.

County Sanitation Districts of Los Angeles County, Long Beach Water Reclamation Plant (Long Beach WRP) Order No. 95-076, CA0054119

- Located at 7400 East Willow Street, Long Beach
- Design capacity of 25 MGD
- Treatment consists of primary sedimentation, activated sludge biological treatment, secondary clarification, coagulation, inert media filtration, chlorination, and dechlorination.
- Tertiary-treated municipal and industrial wastewater is discharged to Coyote Creek at a point 2,200 feet upstream from the confluence with the San Gabriel River, above the estuary
- A portion of the treated effluent is reclaimed for irrigation and regulated under Order No. 87-47.

County Sanitation Districts of Los Angeles County, Whittier Narrows Water Reclamation Plant (Whittier Narrows WRP) Order No. 95-082, CA0053716

- Located at 301 North Rosemead Blvd., El Monte
- Design capacity of 15 MGD
- Treatment consists of primary sedimentation, activated sludge biological treatment, secondary clarification, coagulation, inert media filtration, chlorination, and dechlorination.
- Tertiary-treated municipal and industrial wastewater is discharged via four discharge points:
    - Discharge No. 001 to the San Gabriel River via a point 700 feet upstream from the Whittier Narrows Dam. The treated effluent generally flows down the river to the San Gabriel River Spreading Grounds
    - Discharge No. 002 to Zone 1 Ditch at a point 5,500 feet upstream from its juncture with the Rio Hondo. The treated effluent enters the Rio Hondo at a point about 4,000 feet upstream from the Whittier Narrows Dam and generally flows down the river to the Rio Hondo Spreading Grounds.
    - Discharge No. 003 to a test basin for the study of using reclaimed wastewater for groundwater recharge; there has been no discharge here since 1981 and no plans to discharge here in the immediate future.

- Discharge No. 004 directly to the Rio Hondo via a 27-inch diameter discharge line at a point 1,400 feet upstream from San Gabriel Blvd., above Whittier Narrows Dam. The treated effluent generally flows down the river to the Rio Hondo Spreading Grounds.
- All or a portion of the effluent is reclaimed and is regulated under Board Order No. 88-107. Reclaimed water directed to reuse is not dechlorinated.

County Sanitation Districts of Los Angeles County, Pomona Water Reclamation Plant (Pomona WRP) Order No. 95-078, CA0053619

- Located at 295 Humane Way, Pomona
- Design capacity of 15 MGD
- Treatment consists of primary sedimentation, activated sludge biological treatment, secondary sedimentation, coagulation, inert media filtration, chlorination, and dechlorination.
- Tertiary-treated municipal and industrial wastewater is discharged to the South Fork of San Jose Creek, a tributary of the San Gabriel River, at a point near the interchange of the Pomona and San Gabriel River Freeways, above the estuary.
- During dry weather, virtually all of the treated effluent is reclaimed for landscape and crop irrigation, as well as for industrial processes and is regulated under Order No. 81-34.

POTW Effluent Annual Averages

Constituent	Units	Pomona	Los Coyotes	San Jose Creek		Whittier Narrows	Long Beach
				East	West		
Flow	MGD	9.65	36.22	52.79	29.45	10.27	17.86
pH	pH units	6.98	7.23	7.00	6.97	6.98	7.18
Temperature	°F	76	76	77	77	76	76
BOD	mg/L	6	6	6	5	3	10
TDS	mg/L	506	843	583	560	538	661
Suspended Solids	mg/L	< 2	< 1	2	< 1	< 1	2
Settleable Solids	ml/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

A total of nearly 39,000 acre-feet/year of reclaimed water from the Whittier Narrows, San Jose Creek, and Pomona WRPs were used for groundwater replenishment of the Central Basin in 1997-98. An additional 10,000 acre-feet/year were used for irrigation and industrial use at 390 sites. Thirty-six percent of the reclaimed wastewater produced by these facilities in 1997-98 was reused; the remainder was discharged to the watershed. Use of reclaimed water to recharge the Montebello Forebay has helped reduce the need for use of imported water or natural river water (imported water use decreased from 22,551 acre-feet in 1996-97 to 0 acre-feet in 1998-99 (LA/SG Rivers Watershed Council, in press).

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Types of permitted wastes discharged into the San Gabriel River Watershed:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
DCSOIL – nonhazardous contaminated soil	1	Minor
DCNWTRS – nonhazardous contaminated groundwater	1	Minor
DCONTAC – nonhazardous contact cooling water	1 2	Major Minor
DDOMIND – nonhazardous domestic sewage & industrial waste	5	Major
DMISCEL – nonhazardous wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	4 29	Minor General
DNONCON – nonhazardous noncontact cooling water	3	Minor
DPROCES – nonhazardous process waste (produced as part of industrial/manufacturing process)	1 1	Major Minor
DSTORMS – nonhazardous stormwater runoff	1 7	Major Minor
DWSHWTR – nonhazardous washwater waste (photo reuse washwater, vegetable washwater)	1	Minor
HCNWTRS – hazardous contaminated groundwater	7 6	Minor General
HPROCES – hazardous process waste (produced as part of industrial/manufacturing process)	1	General
HSTORMS – hazardous stormwater runoff	1	Major
IMISCEL – inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage)	2	General

(California Regional Water Quality Control Board – Los Angeles Region files)

Hazardous – influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards

Designated – influent or solid wastes that contain nonhazardous wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations

Inert – influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

In addition. approximately 70 oil wells are located in the Whittier Narrows below elevation 230 feet. The wells pre-date the construction of the dam and are part of the Montebello Oil Field discovered in 1918 (U.S. Army Corps of Engineers LA District, 1998).

Current Water Quality Impairments

(California Regional Water Quality Control Board – LA Region, 2000)

303(d) impairments in watershed and projected TMDL schedule:

303(d) Listed Waterbody (Reach)	Pollutant/ Impairment	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
San Gabriel River Reach 3 (Whittier Narrows to Ramona)	toxicity	nitrogen and its effects	1999/00	2002/03	
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	NH3				
San Gabriel River Reach 1 (Estuary to Firestone)	NH3				
San Gabriel River Reach 1 (Estuary to Firestone)	algae				
San Gabriel River Reach 1 (Estuary to Firestone)	toxicity				
San Jose Creek Reach 1 (SG confluence to Temple St.)	NH3				
San Jose Creek Reach 1 (SG confluence to Temple St.)	algae				
Coyote Creek	NH3				
Coyote Creek	algae				
Coyote Creek	toxicity				
Walnut Creek	toxicity				
Walnut Creek	pH				
San Gabriel River East Fork	trash	trash	1998/99	1999/00	
Legg Lake	trash	trash	2000/01	2008/09	
Puddingstone Reservoir	DDT, PCBs, chlordane	PCBs & pest.	2000/01	2007/08	
El Dorado Lakes	Hg	metals	2000/01	2005/06	
El Dorado Lakes	Cu, Pb				
Puddingstone Reservoir	Hg				
Legg Lake	Cu, Pb				
Santa Fe Dam Park Lake	Pb, Cu				
Coyote Creek	abnormal fish histology	Dependent on cause	2000/01	2005/06	Further Assessment needed - cause of abnormalities unknown
San Gabriel River Reach 1 (Estuary to Firestone)	abnormal fish histology				
San Gabriel River Estuary	abnormal fish histology				
El Dorado Lakes	algae, NH3, eutroph.	nitrogen and its effects	2006/07	2010/11	
El Dorado Lakes	pH				
Crystal Lake	algae, nutrients				
Legg Lake	NH3				
Legg Lake	pH				
Legg Lake	odors				
Puddingstone Reservoir	low DO, org. enrichment				
Santa Fe Dam Park Lake	pH				
San Jose Creek Reach 1 (SG confluence to Temple St.)	Pb	metals	2000/01	2004/05	
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	Pb				
San Gabriel River Estuary	As				
Coyote Creek	Ag				
San Jose Creek Reach 1 (SG confluence to Temple St.)	coliform	coliform	2006/07	2010/11	
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	coliform				
San Gabriel River Reach 1 (Estuary to Firestone)	coliform				
Coyote Creek	coliform				

Typical Data Ranges for Waters Listed as Impaired:

Pollutant/ Impairment	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3-28.0 mg/l to protect against acute toxicity	ND - 21.1 mg/l (mean of 10.1±4.1)	San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) San Gabriel River Reach 1 (Estuary to Firestone) San Jose Creek Reach 1 (SG confluence to Temple St.) Coyote Creek Legg Lake El Dorado Lakes
toxicity	Basin Plan narrative objective	0 – 100% survival	San Gabriel River Reach 3 (Whittier Narrows to Ramona) San Gabriel River Reach 1 (Estuary to Firestone) Coyote Creek Walnut Creek
algae	Basin Plan narrative objective		San Gabriel River Reach 1 (Estuary to Firestone) San Jose Creek Reach 1 (SG confluence to Temple St.) Coyote Creek El Dorado Lakes
Eutrophication	Basin Plan narrative objective		El Dorado Lakes
pH	Basin Plan numeric objective: 6.5 - 8.5 pH units	6.9 - 9.4 pH units (mean of 8.5±0.6)	Walnut Creek El Dorado Lakes Legg Lake Santa Fe Dam Park Lake
odors	Basin Plan narrative objective		Legg Lake
low DO, organic enrichment	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	0.1 - 14.9 mg/l (mean of 4.3±3.5)	Puddingstone Reservoir Crystal Lake
trash	Basin Plan narrative objective		San Gabriel River East Fork Legg Lake
Lead	USEPA water quality criteria: varies based on hardness but typically 3.2 - 25 ug/l	100 ug/l (maximum)	San Jose Creek Reach 1 (SG confluence to Temple St.) San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) Santa Fe Dam Park Lake El Dorado Lakes Legg Lake
Arsenic (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 200 ng/g	240 - 300 ng/g (tissue)	San Gabriel River Estuary
Copper	USEPA water quality criteria varies based on hardness but typically 12 - 47 ug/l	90 ug/l (maximum)	Legg Lake El Dorado Lakes Santa Fe Dam Park Lake
Silver	USEPA water quality criteria varies based on hardness but typically 4.1 - 65 ug/l	30 ug/l (maximum)	Coyote Creek
Mercury (tissue)	NAS guidelines (tissue): 500 ng/g	510 ng/g (tissue)	Puddingstone Reservoir El Dorado Lakes
coliform	Basin Plan numeric objective: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml	ND - 240000 MPN/100ml	San Jose Creek Reach 1 (SG confluence to Temple St.) San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) San Gabriel River Reach 1 (Estuary to Firestone) Coyote Creek
DDT	State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	25 - 36 ng/g (tissue)	Puddingstone Reservoir
PCBs	State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	54 - 65 ng/g (tissue)	Puddingstone Reservoir
chlordane	State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	16.1 - 31.7 ng/g (tissue)	Puddingstone Reservoir
abnormal fish histology	Basin Plan narrative objective		Coyote Creek San Gabriel River Reach 1 (Estuary to Firestone) San Gabriel River Estuary

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Overview of Existing Monitoring Data

Receiving Water Monitoring Data

What follows is an overview of the available receiving water monitoring data from 1988 to present; some figures are included in this document (electronically also as Figures.xls). All of the data and the rest of the figures are available electronically from the Regional Board as Excel 97 files (with the exception of one report) rather than as hardcopy due to the very large amount of information the files contain. As an informational note, the CRWQCB-LA Region ambient monitoring database contains sampling results from multiple agencies including the CRWQCB, US Forest Service, Department of Water Resources, and the Los Angeles County Department of Public Works. Due to its large volume of data, information in the ambient monitoring database has been separated into files based on broad categories of constituents. In some cases, data from the CSDLAC submittal were added into the constituent files in order to create one file with all chlorides data, for instance.

This overview of the data is not meant to represent an official Water Quality Assessment. Due to time constraints, no statistical analyses were performed. Rather, it is a qualitative review of available information on water quality. At some locations, only older data are available, while at other locations only more recent data exist. The intent of this overview is to generally describe patterns in various constituents which have been sampled in the watershed, to highlight where future data gathering may be most fruitful or needed, and to suggest where a more thorough data analysis could yield decisions for Water Quality Assessment purposes.

•**CRWQCB, LA Region ambient monitoring database:** SGRiverMetals_ambientonly.xls, SGRiverColiform_ambientonly.xls, SGRiverChloride_alldata.xls, SGRiverNutrients_alldata.xls
•**County Sanitation Districts of Los Angeles County electronic submittal of receiving water monitoring data previously submitted in report format:** SGRiver LACSD RW Data 1995-1999.xls
•**Los Angeles County electronic submittal of municipal stormwater monitoring data:** MunStormwaterSGRiver1997-98.xls **and** MunStormwaterSGRiver1998-99.xls

Monitoring frequency: Parts of the watershed have been monitored much more regularly and frequently than others **(see maps in Figures 1-6)**. The headwaters (based on the data available in the Regional Board ambient database) were monitored fairly intensively in the early 1990s but very infrequently since then. A large monitoring effort was conducted from 1988-1994 by the LA County Department of Public Works at a large number of sites; monitoring under the current municipal stormwater permit is much less intense and at fewer sites. For the most part, sampling is concentrated in the mainstem of the river and in tributaries near confluences (as well as in the vicinity of major point sources for which data from 1995-1999 were examined). As a consequence, much of the tributaries Walnut Creek, San Jose Creek, and Coyote Creek have not been monitored yet these, through the data available at the confluences, appear to be major contributors of pollutants to the mainstem of the river. Also of note are the large storm drains connecting to the mainstem below the spreading grounds which may be worthy of individual monitoring due to patterns seen in the data, particularly for coliform.

When one considers the unusual nature of this watershed, however, a fairly unusual monitoring program may be warranted. Waters from the upper part of the watershed often do not get past the Santa Fe Dam and its spreading grounds. Waters entering the mainstem from San Jose and Walnut Creeks may be diverted through Whittier Narrows area to the Los Angeles River. Those waters remaining in the San Gabriel River will often recharge at the downstream spreading grounds. From the beginning of the concrete portion on downstream is a continuously flowing river through discharges from POTWs as well as through urban runoff. It is joined by Coyote Creek just before meeting the unlined tidal prism.

General observations: The original datasets were in some cases reduced or streamlined to eliminate very infrequent sampling episodes or those not collected on the same date. At times, earlier and later datasets are compared; this is pointed out where it occurs.

- Nutrient and related data: Nitrate-N, nitrite-N, ammonia-N, total phosphate, and pH data are generally available for most of the sites monitored. Nitrate (as NO_3), BOD_5, chemical oxygen demand (COD),

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total organic carbon (TOC), and dissolved oxygen data are also sporadically available. For example, the County Sanitation Districts of Los Angeles County (CSDLAC) monitors BOD_5 and COD but not TOC. Other agencies have occasionally monitored for BOD_5 and TOC but never COD. This is unfortunate since the latter parameter has shown the most interesting patterns which will be discussed further below.

Certain parameters can appropriately be generalized into average values (nitrate-N, COD, and total phosphate are examples) since temporal fluctuations are not great in this dataset. Dissolved oxygen levels however fluctuate greatly and must be viewed on a finer scale.

Not surprisingly, nutrient concentrations tend to be quite low in the upper watershed (in the West, North, and East Forks). The average concentration of total phosphate in the North Fork, however, is a little higher than might be expected. pH averages slightly over 8.0 mg/l.

The next site where an array of parameters is collected is just above the confluence with San Jose Creek, many miles downstream. Here, nutrient concentrations are marginally higher than in the upper watershed. pH averages slightly under 8.0 mg/l.

A POTW discharges to San Jose Creek just upstream of its confluence with the main river. Ammonia and nitrate-N are already higher upstream of the POTW than in the upper watershed. Average ammonia, nitrate-N, and total phosphate levels increase noticeably below the POTW while pH averages just under 7.5 mg/l.

Sampling data for the mainstem below the confluence with San Jose Creek is again somewhat sparse until the San Gabriel Spreading Grounds, below the Whittier Narrows Dam. These data were collected from 1988-1994 and include mostly nitrite-N, pH, total phosphate, and TOC but comparisons to sites elsewhere in the watershed are difficult due to the availability of only this older dataset.

The next two sites with a large amount of data are each located downstream of a POTW within the concrete-lined portion of the main river. Nutrient concentrations have increased considerably by the lowermost of the two sites. COD also increases as one progresses downstream.

The next two sampling sites further downstream are much closer to the tidal prism and indeed the lowermost one is influenced at times by tidal overwash onto the concrete. Nutrient levels, particularly total phosphate, are considerably higher here than in the area above the concrete portion of the river. COD levels continue to rise. However, while BOD5 levels were rather high in the older dataset associated with the more upstream site, levels were considerably lower in the more recent data at the downstream site.

As previously mentioned, most of the monitoring in Coyote Creek is concentrated around the major point source, a POTW. An older dataset exists for a site further upstream. The greatest difference in parameters occurs in ammonia-N and total phosphate concentrations which rise downstream of the POTW and are rather low upstream. Nitrate-N levels however are rather uniform both upstream and downstream of the POTW.

Coyote Creek enters the main river at the tidal prism. COD rises sharply within the tidal prism. By contrast, after initially high levels, ammonia-N, nitrate-N, nitrite-N, and total phosphate levels fall sharply.

As described earlier in this document, various reaches of the river are 303(d)-listed as impaired for ammonia, toxicity, algae, or pH.

- Bacteriological data: Medians were calculated in order to evaluate bacteriological data for general trends. Total coliform was collected at all sites with fecal coliform and enterococcus collected at some. Coliform levels fluctuated greatly at many locations.

  What limited data there were for the upper watershed showed consistently low levels of total and fecal coliform. The tributaries Coyote and San Jose Creeks exhibited high median levels of total and fecal coliform as well as enterococcus (higher than the mainstem). Of particular interest is an abrupt increase in median total coliform levels in the concrete portion of the main river. A number of large storm drains enter the river in this stretch.

Various reaches of the main river, San Jose Creek, and Coyote Creek are 303(d)-listed as impaired for coliform.

- Metals data: Metals were generally not detected in the upper watershed and only occasionally detected elsewhere in the watershed; they were found most often in the lowermost part of the watershed. Arsenic and zinc were the metals most frequently detected. It can likely be assumed that the majority of sampling took place on dry weather days; wet weather storm sampling is discussed below and exhibited very different results. Various reaches of the river, its tributaries, or lakes associated with reservoirs are currently 303(d)-listed as impaired for lead, copper, arsenic (in tissue), silver, and mercury (in tissue).

- Chlorides data: Chlorides are higher in Coyote Creek than in San Jose Creek; chloride levels in the mainstem above the tidal prism are slightly lower than those in San Jose Creek. It's also clear from the data that full strength seawater is not reached until well into the tidal prism.

- Organics data: Except for lindane, other organics were rarely detected.

Specific findings

- Nutrients and related data: Dissolved oxygen is the most variable parameter related to nutrient concentrations. At times, average concentrations may be acceptable but extreme fluctuations may be occurring from week to week or from month to month (and probably daily although samples are generally not obtained that often).

  A fairly large amount of dissolved oxygen data were obtained for parts of the upper watershed in the early 1990s. Concentrations averaged 9.8 mg/l with little fluctuation. Availability of oxygen to aquatic life is temperature-dependent; with the generally low temperatures of the upper watershed, much of the oxygen was likely available for use.

  Dissolved oxygen levels fluctuate greatly in the rest of the watershed with concentrations in San Jose Creek fluctuating the least and those in Coyote Creek fluctuating the most, especially in recent years **(Figure 7)**. The fluctuations are extreme at some sites. Although some reaches are 303(d)-listed for algae, no part of the river or its tributaries are currently listed for low DO/organic enrichment or eutrophication.

  Ammonia-N concentrations were also evaluated in more detail. **(Figures 8 and 9)** Ammonia-N concentrations also fluctuate greatly at times. The graphed locations (other than those in the tidal prism and San Jose Creek) are in concrete-lined portions of the river. San Jose Creek water would likely not reach the lower river; however, it is clear that considerable ammonia enters the more sensitive tidal prism stretch of river and persists for some distance. Often, nearly half of the total nitrogen in the river is in the form of ammonia. Much of the lower reaches of the river and its tributaries are on the 303(d) list for ammonia exceedances.

  Chemical oxygen demand is higher in Coyote Creek than in either San Jose Creek or the upper parts of the concrete-lined portion of the main river. **(Figure 10)** Levels increase gradually at the more downstream stations until the tidal prism is reached where levels increase dramatically and continue to rise all the way to the mouth of the river. Also, COD levels have greatly increased over the past two years. This pattern is not consistent with that for BOD and indeed for many other parameters which tend to decrease partway into the tidal prism. COD in the effluent of tertiary treatment plants is generally less than 20 mg/l. There may be sources of industrial waste entering the lower watershed which are currently unknown and are apparently not associated with stormwater runoff since levels are high virtually year-round. Also of interest is an apparent decrease in overall BOD levels in the watershed when comparing the older dataset (1988-1994) with the later dataset (1995-1999) although the two datasets do not overlap sampling sites exactly (see later discussion on BOD levels in stormwater).

- Bacteriological data: Although highly variable, total coliform levels in San Jose and Coyote Creeks have rarely dropped below 1,000 mpn/100ml during the last five years. They are both currently on the 303(d) list for coliform exceedances. The lower reaches of the main river are also 303(d)-listed for coliform; however, there are some differences in total coliform concentrations among the current sampling sites (CSDLAC data). **(Figures 11 and 12)** Coliform levels below the SJCWRP discharge point (in the main river) are much lower than further downstream which may indicate a nearby source, possibly through a storm drain. Levels below the SJCWRP appear to fluctuate more with the seasons (and, presumably, with storm runoff) while levels further downstream are more consistently high. The beginning section of the tidal prism contains very high levels of coliform and rarely drops below 1,000 mpn/100ml. The estuary is not currently 303(d)-listed for coliform.

- Metals data: Coyote Creek is currently 303(d)-listed for silver bioaccumulated in tissue. Recent (non-stormwater) data are largely nondetect for metals. The estuary is also listed for arsenic in fish tissue through the state's Toxic Substances Monitoring Program. It is unclear from where arsenic may be originating since it is generally found in the water column at low levels. More intense monitoring (with appropriately low detection limits) would be useful to update the status of metals impairments.

- Chlorides data: It appears from **Figure 13** that the POTW discharge in Coyote Creek is ameliorating high chloride levels coming from further upstream.

LA County Department of Public Works, electronic copies of stormwater monitoring data for Storm Years 1997-98 and 1998-99 – specific findings

Sampling sites are located in Coyote Creek north of Willow Street (not a required site) and in the San Gabriel River south of the Whittier Narrows Dam.

- 1997-98 storm season

  Bacteriological data: Not surprisingly, very high total and fecal coliform as well as fecal streptococcus levels were found in the San Gabriel River during storm events (coliform samples were not collected in Coyote Creek).

  Nutrients (and related) data: In general, a "first flush" effect was seen where nutrient concentrations were higher following the first storm and gradually lower throughout the season. Nutrient concentrations were not outside the range found during dry weather although varied considerably from storm to storm. BOD and COD levels, however, were noticeably elevated over that found during dry weather and were higher in Coyote Creek than in the San Gabriel River.

  Chlorides data: It is clear from the chloride data that Coyote Creek in particular receives a considerable amount of storm runoff (relative to baseline flow) due to the greatly lowered chloride concentrations during some storms.

  Metals data: Metals data were compared with estimated water quality objectives for metals (hardness-adjusted). Potential metals exceedances occurred on 88% of the monitored days (at both an acute and chronic level) at the Coyote Creek site. Potential chronic objective exceedances occurred at the San Gabriel River site on 66% of the monitored days while potential acute exceedances occurred on 33% of the monitored days.

  Copper and zinc were the most common problem metals in Coyote Creek. Cadmium and lead were also occasionally at high levels. Many other metals were not detected. The creek is 303(d)-listed for silver only (in tissue) which did not occur at excessive levels in the water column sampling.

Potential exceedances at the San Gabriel River site involved copper, lead, and zinc to a fairly equal extent. The river (one reach) is 303(d)-listed for lead but not copper or zinc.

Semivolatiles and pesticides: These were detected very infrequently.

- 1998-99 storm season

During this storm season, some sampling occurred on non-storm days.

Bacteriological data: The Coyote Creek site was not monitored for coliform. At the San Gabriel River site, one sampling event occurred on a non-storm flow day. Coliform levels were much lower on that date than on early storm-year sampling dates (although still high relative to body contact standards). Later in the storm-year, coliform levels during storm days were much lower (compared to the beginning of the storm-year) and comparable to the one dry weather sample taken. Except for during the first two sample events, fecal coliform and fecal streptococcus were not exceptionally high; total coliform was always high.

Nutrients (and related) data: For Coyote Creek, this year also there appears to have been a "first flush" effect for some constituents (notably nitrate-N and ammonia-N). This effect appeared to occur during what were likely the first significant storm of the season in December. Levels were much higher than in the early season dry-weather sampling event for virtually all constituents except BOD which appeared to fluctuate independent of storm flows. Nutrient levels remained quite high in the second dry sampling event in January. Nutrient levels dropped somewhat throughout the rest of the storm season.

A "first flush" effect was harder to discern in the San Gabriel River data. It's possible that enough nutrients are carried during regular flows to mask storm effects.

Chlorides data: Chlorides levels dropped considerably during storms in Coyote Creek and more so than in the San Gabriel River.

Metals data: There were far fewer monitoring days with potential exceedances during this storm season than during the previous storm season. Twelve percent of the sampling days at the Coyote Creek site resulted in potential chronic effect level exceedances (copper, zinc, and selenium) while there was only one sampling day where potential acute level exceedances occurred (copper and zinc). Eight percent of the sampling days at the San Gabriel River site resulted in potential chronic level exceedances with no potential acute level exceedances.

Semivolatiles and pesticides: These were detected very infrequently.

Toxicity Study of the Santa Clara River, San Gabriel River, and Calleguas Creek, December 1996

Copies of this report may be obtained from the Regional Board. An electronic version is not available.

Much of the sampling took place in the early 1990s. Persistent toxicity problems were noted in Walnut Creek as well as in Coyote Creek and the San Gabriel River near their confluence; persistent toxicity was also seen in the tidal prism. Attempts were made to determine the causes of toxicity; an organophosphate (such as diazinon) and/or a metals (such as zinc) were implicated at times. A number of fish collected at several sites in the lower watershed exhibited abnormal histopathology associated with pollutants such as metals or certain organics. Coyote Creek and parts of the San Gabriel River are 303(d)-listed for abnormal fish histology. The San Gabriel River Estuary is not currently 303(d)-listed for toxicity.

Effluent Monitoring Data

The majority of this information is only available by visiting the Regional Board office by appointment for file review.

CRWQCB, LA Region NPDES (effluent) program monitoring and compliance inspection files

The POTWs in the watershed are generally meeting permit limitations and, except for ammonia-N (and nitrogen effects in general), do not appear to be greatly contributing to current 303(d)-listed exceedances.

Effluent monitoring data from a subsample of other types of discharges (minors) were also evaluated. A number of discharges are of treated groundwater from cleanup of volatile organic compounds. pH readings have been quite high (or at times low) at some sites. Nitrate levels were also elevated in some of these discharges although this parameter was not monitored regularly. A number of sites discharge stormwater runoff under individual NPDES permits. For the most part these permits do not contain limits for metals; they instead focus on parameters such as oil & grease, suspended solids, and pH. There is usually an annual metals scan required and some metals are fairly elevated at times. There are a few sites discharging condensate water with extra monitoring in one case revealing rather high levels of ammonia, COD, and oil & grease.

CRWQCB-LA Region. 1996-1997 Annual Report for Storm Water Industrial Activities General Permit – Analysis of the Sampling Results. August 1988. Final Draft.

The data analyzed in this report were submitted under a statewide General Industrial Activities Storm Water Permit which was initially issued in 1991 and reissued in 1997. The permit requires each regulated facility to prepare and implement a Storm Water Pollution Prevention Plan, develop and implement a monitoring program, and submit an annual self-monitoring report. There are approximately 500 facilities covered by the industrial storm water permit in the San Gabriel River Watershed. The report also addressed some data from 1992-1993. A large number of data exist for the period from 1993 to 1996 but the resources needed to make the data available electronically do not.

Results for the Los Angeles and San Gabriel Rivers Watersheds were combined in this report but it will be assumed that the combined data may be loosely representative of one or the other watershed. It was reported that out of the approximately 2,000 facilities reporting pH results, 13% were outside of the 6.0 – 9.0 mg/l benchmark level in 1996-1997; 24% were above the 100 mg/l benchmark level for total suspended solids; 25% were above the 200 μmhos/cm benchmark level for specific conductance; 14% were above 15 mg/l benchmark level for oil & grease; and 6% were above the 110 mg/l benchmark level for total organic carbon. Some of the samples exceeding the benchmark were orders of magnitude higher. The results in 1992-1993 were similar.

Recommendations for Future Monitoring

- Investigate potential contributions from storm drains of coliform and COD in lower San Gabriel River
- Investigate sources of high coliform in Coyote Creek
- In general, evaluate water quality in Walnut Creek, San Jose Creek, and Coyote Creek more intensively including using toxicity tests and Toxicity Identification Evaluations
- Investigate the need to continue 303(d)-listings for arsenic and silver
- Evaluate need to newly 303(d)-list reaches for copper and/or zinc
- Determine impairment status of lead in watershed
- Evaluate need to 303(d)-list estuary for low dissolved oxygen and ammonia
- Include nitrate monitoring for discharges of treated groundwater; in general, include COD monitoring for larger discharges

Potential Long-term Activities

The Regional Board considers these as issues of concern in the watershed for the agency over the long-term (California Regional Water Quality Control Board – Los Angeles Region, January 2000)

- Development of a coordinated watershed monitoring program
- Hydrologic study of the estuary to evaluate mixing dynamics and effects on water quality and beneficial uses
- Identification of seasonal variations in water quality
- Evaluation of fish tissue from fish in the lower river and estuary
- Determination of the fate of ammonia in the estuary
- Evaluation of habitats in the middle/lower river
- Evaluation of impacts from reservoir cleaning on water quality, particularly fisheries-related
- Evaluation of mining on instream beneficial uses
- Evaluation of success of trash TMDL efforts in upper river
- Evaluation of impacts from industrial stormwater in the watershed
- Identification of sources of contributing flows to reaches and tributaries
- Identification of dry segments in reaches and tributaries
- Consideration of TMDL-related issues
- Implementation of biological monitoring

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U.S. Army Corps of Engineers, Los Angeles District, Reservoir Regulation Section website on Santa Fe Dam – http://www.spl.usace.army.mil/resreg/htdocs/snfe.html

Water Replenishment District of Southern California. Draft Initial Study/Negative Declaration for the Alamitos Barrier Reclaimed Water Project. Prepared by Psomas and Associates. September 1998.

Figures

Figure 1

San Gabriel River Watershed - Sampling Sites in Upper Watershed

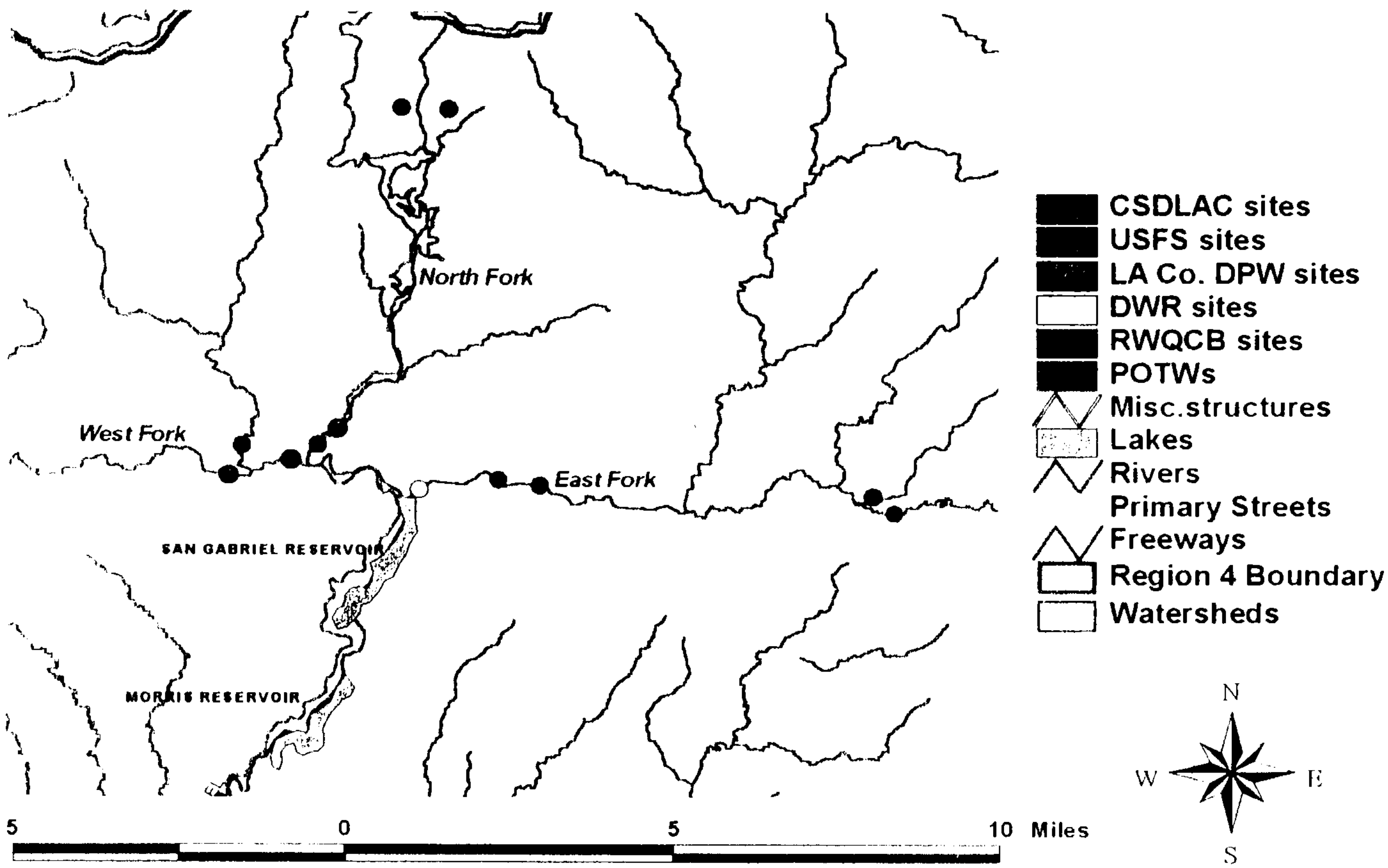

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Figure 2

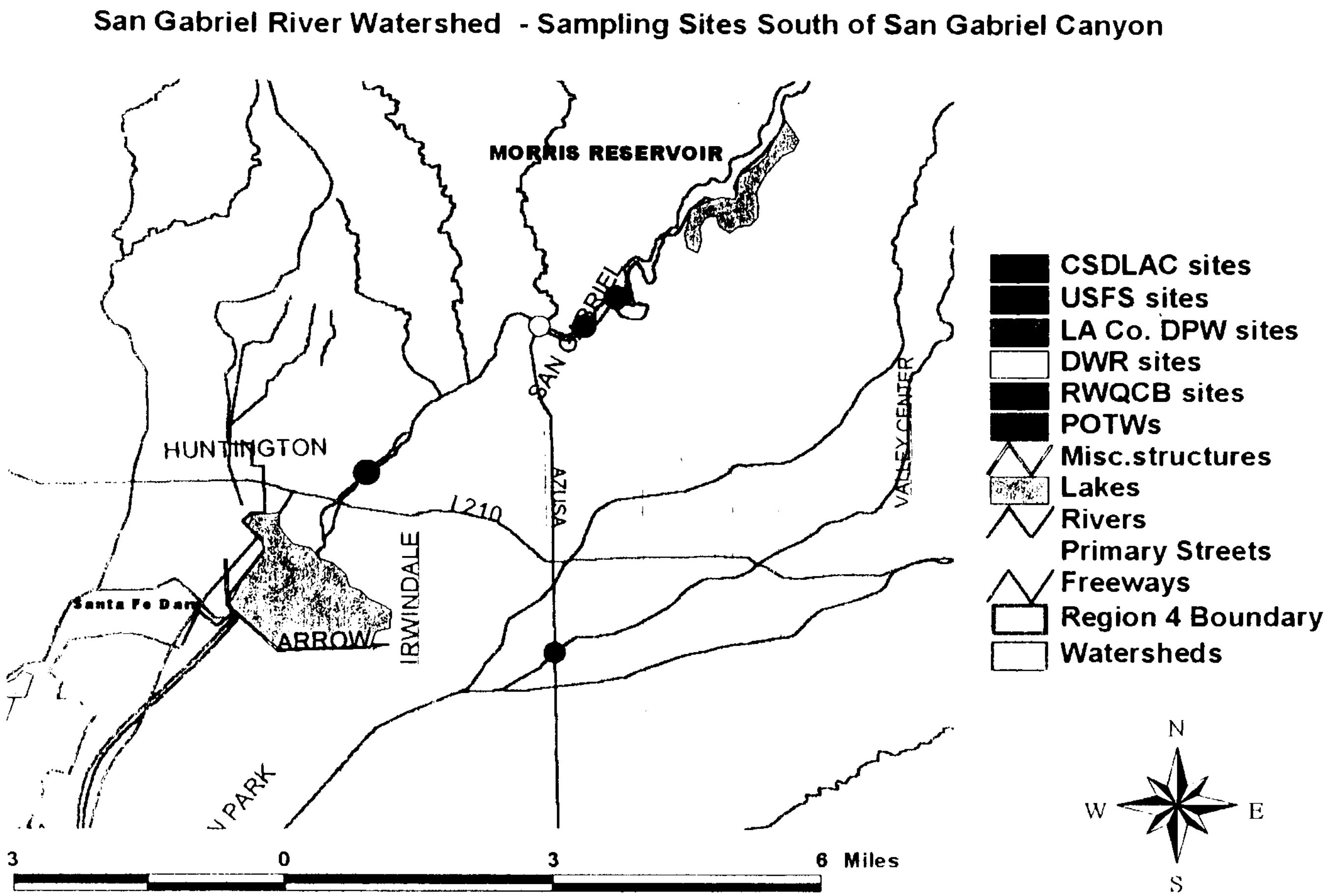

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Figure 3

San Gabriel River Watershed - Sampling Sites South of San Gabriel Canyon

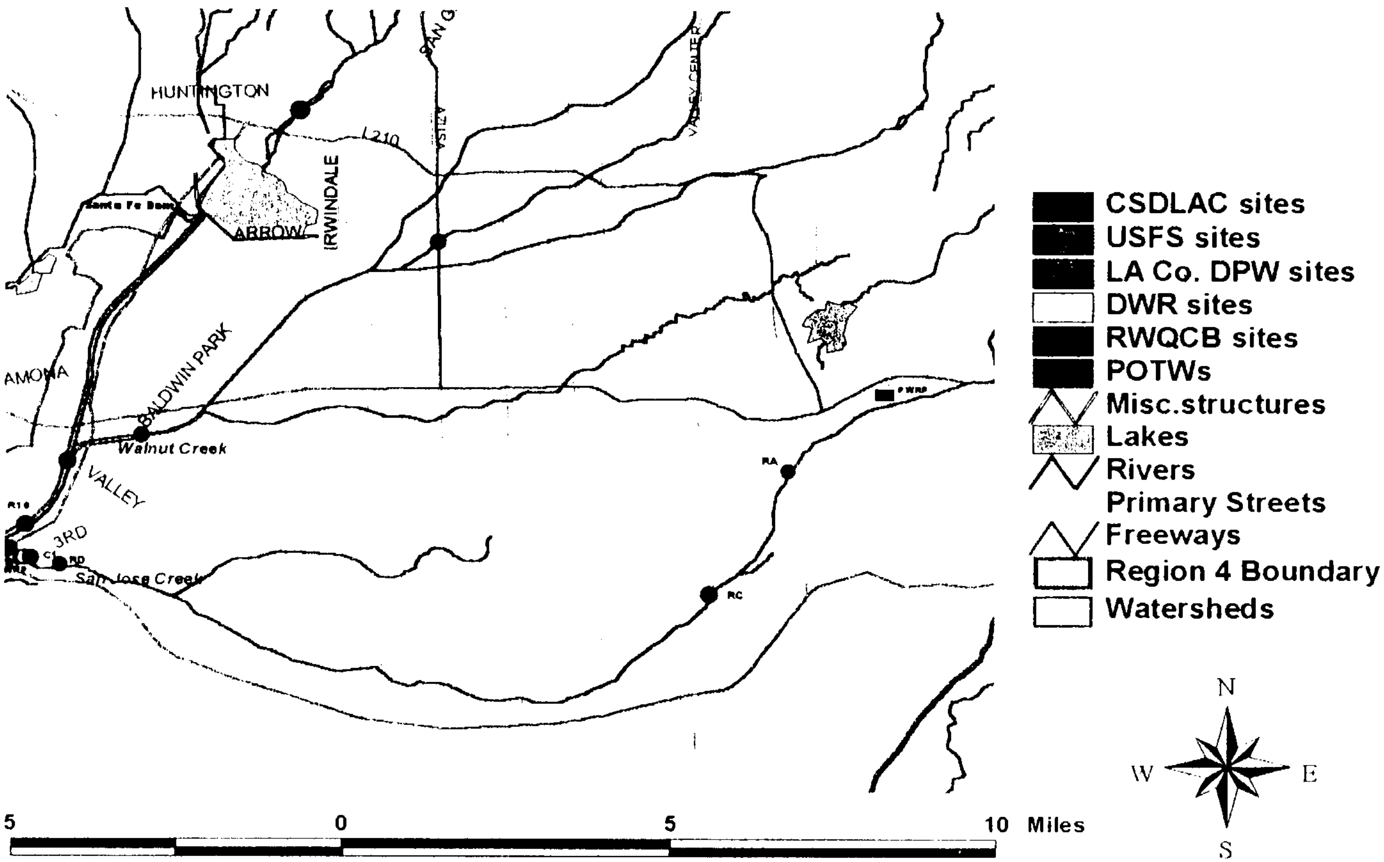

Figure 4

San Gabriel River Watershed - Sampling Sites in Area of San Jose and Walnut Creeks

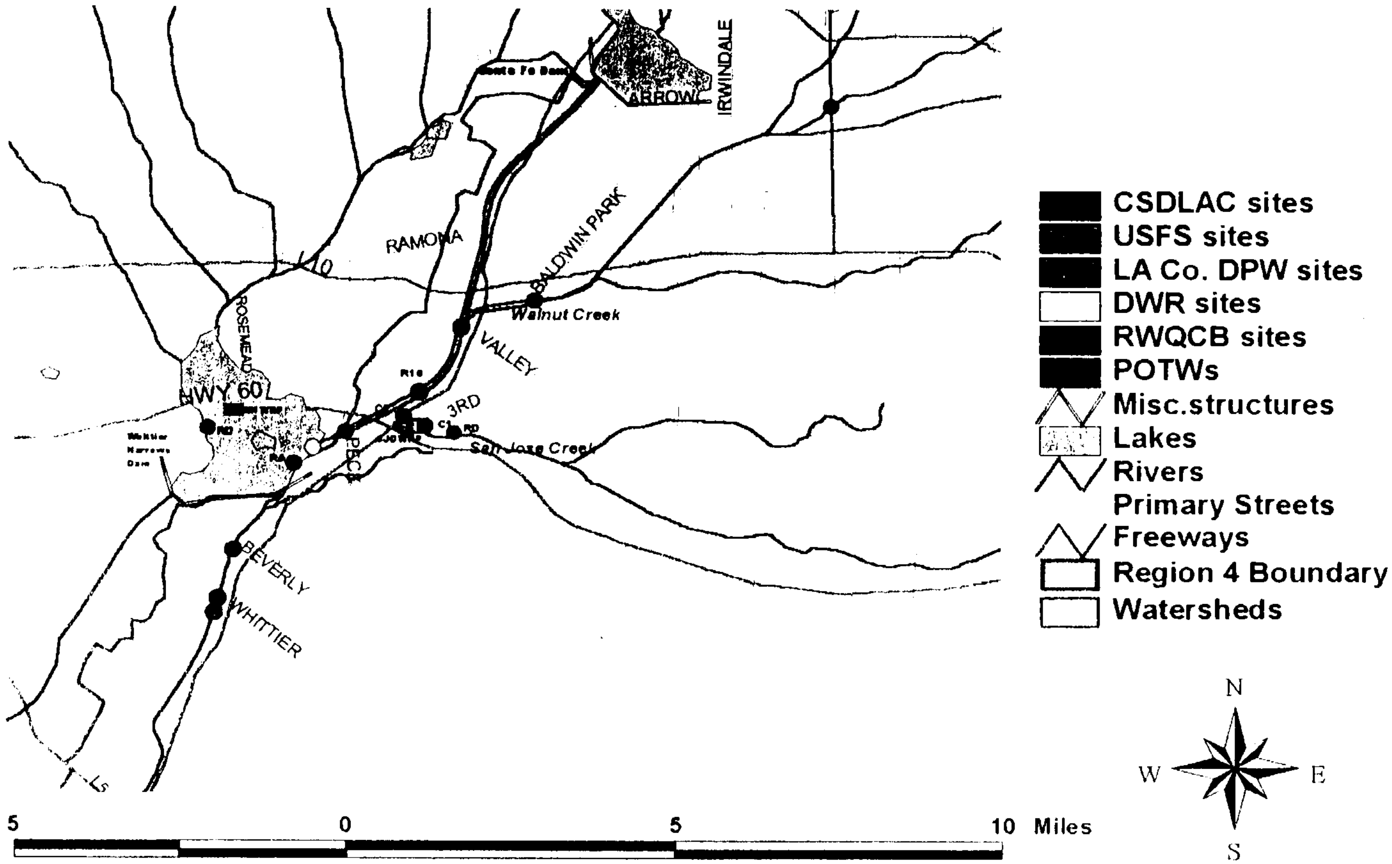

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Figure 5

San Gabriel River Watershed - Sampling Sites North of Coyote Creek

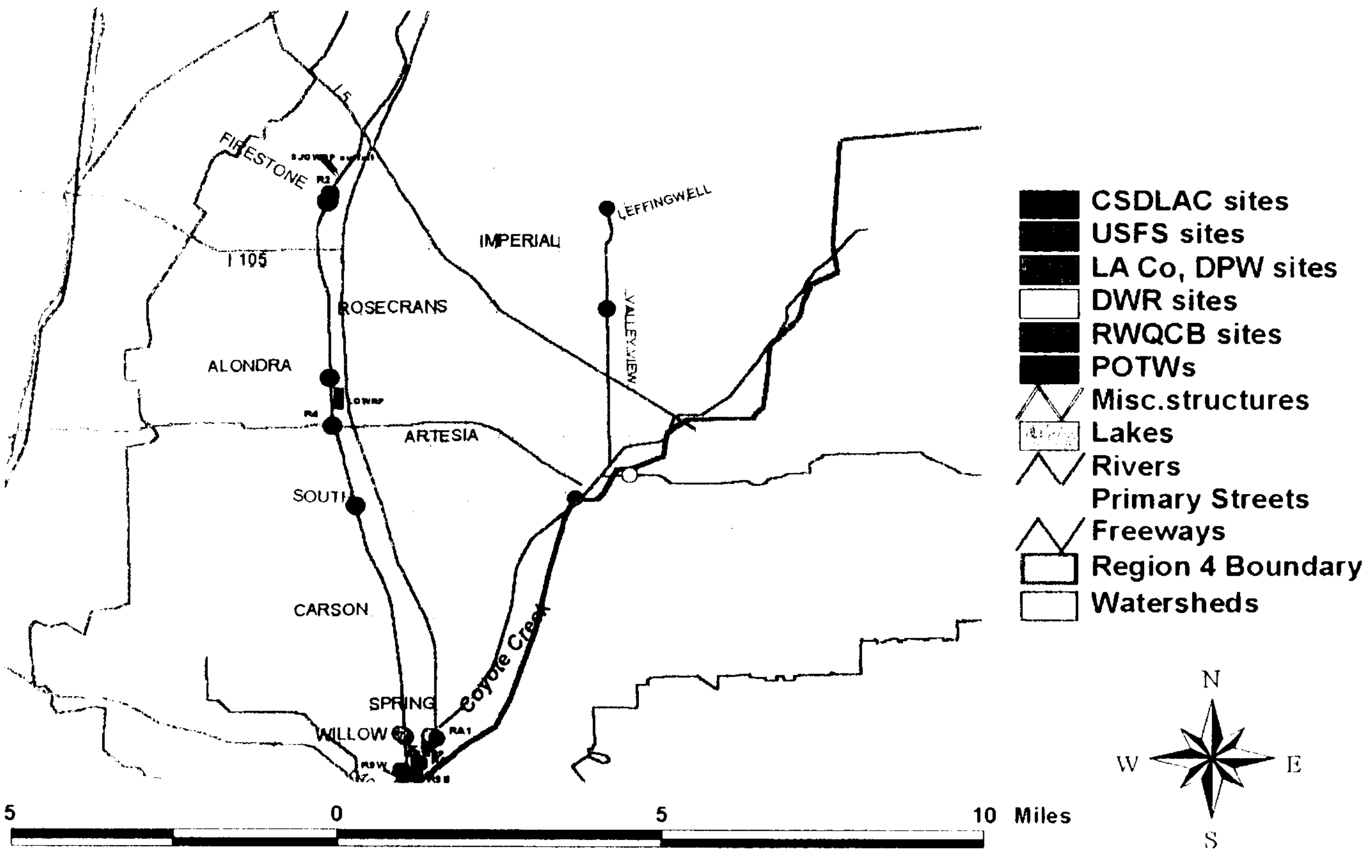

Figure 6

San Gabriel River Watershed - Sampling Sites South of Coyote Creek

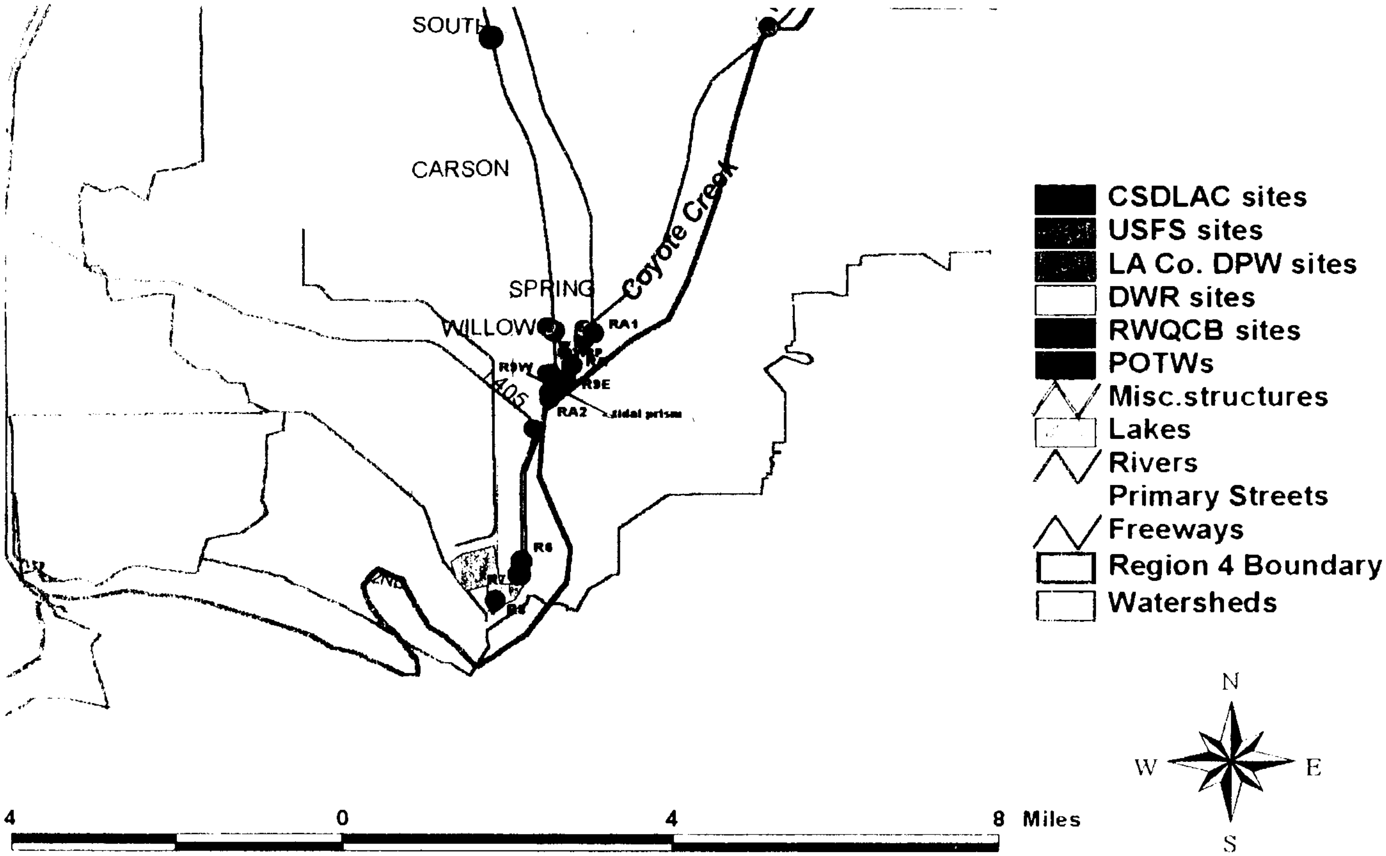

Figure 7

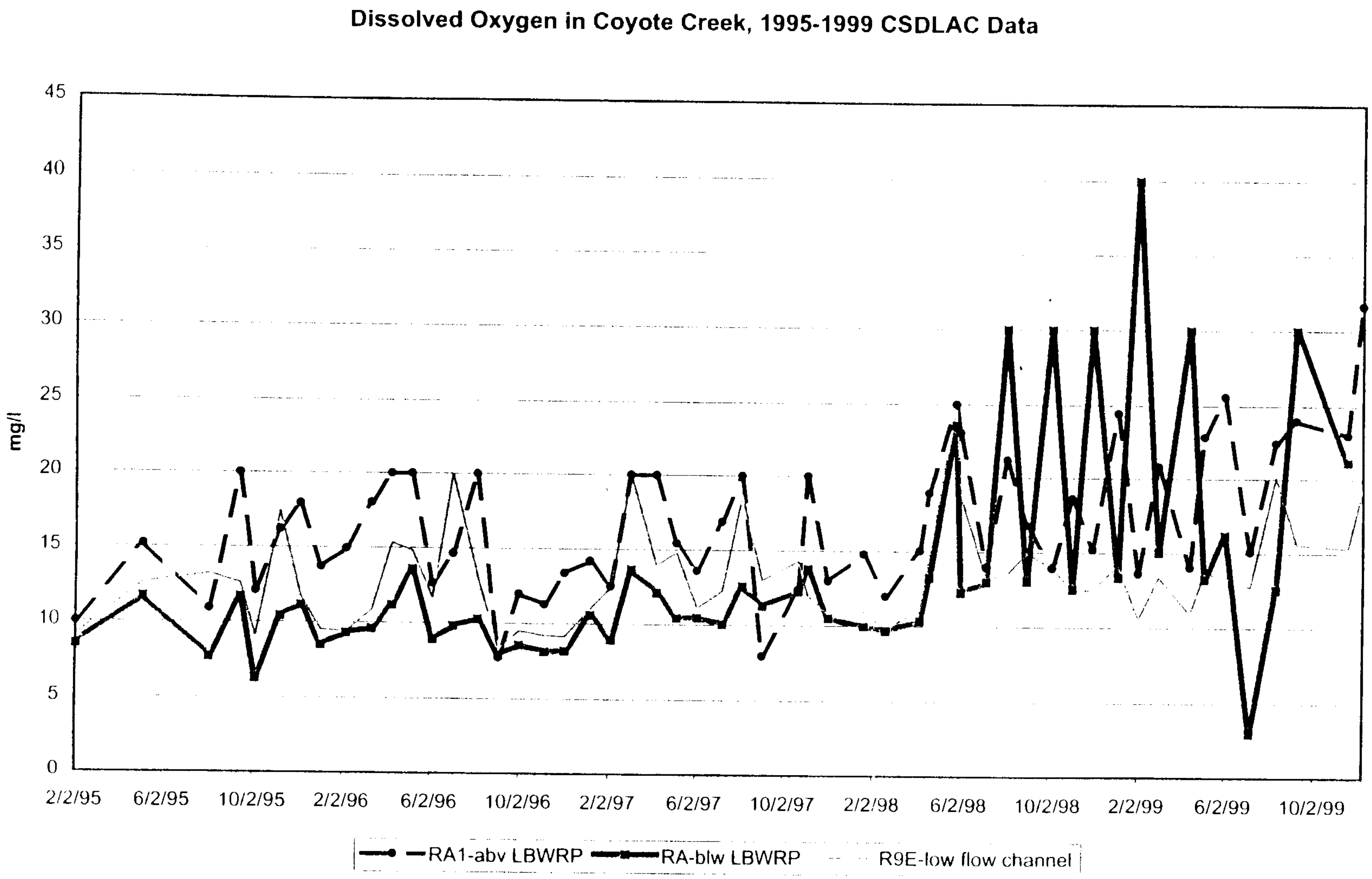

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Figure 8

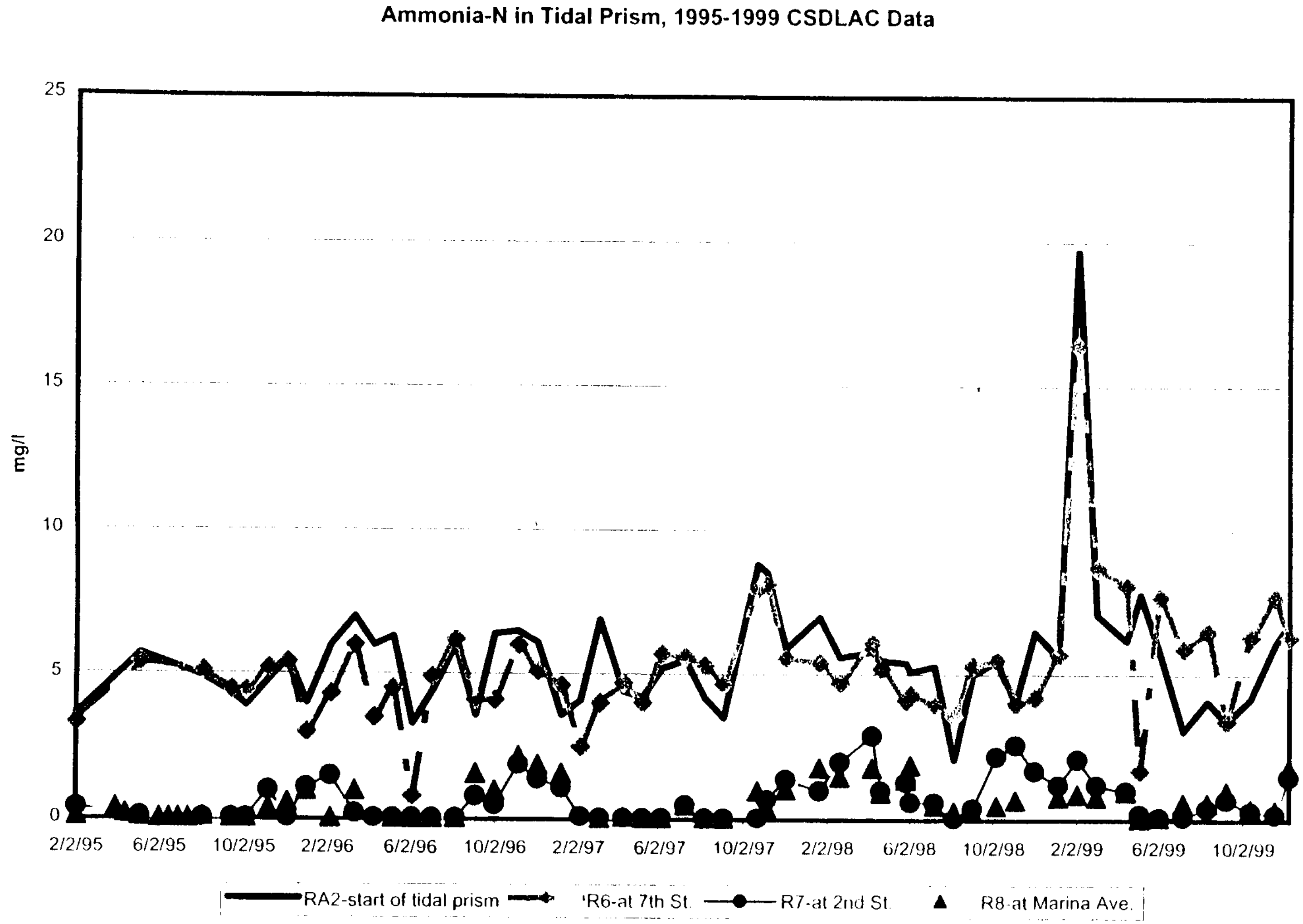

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Figure 9

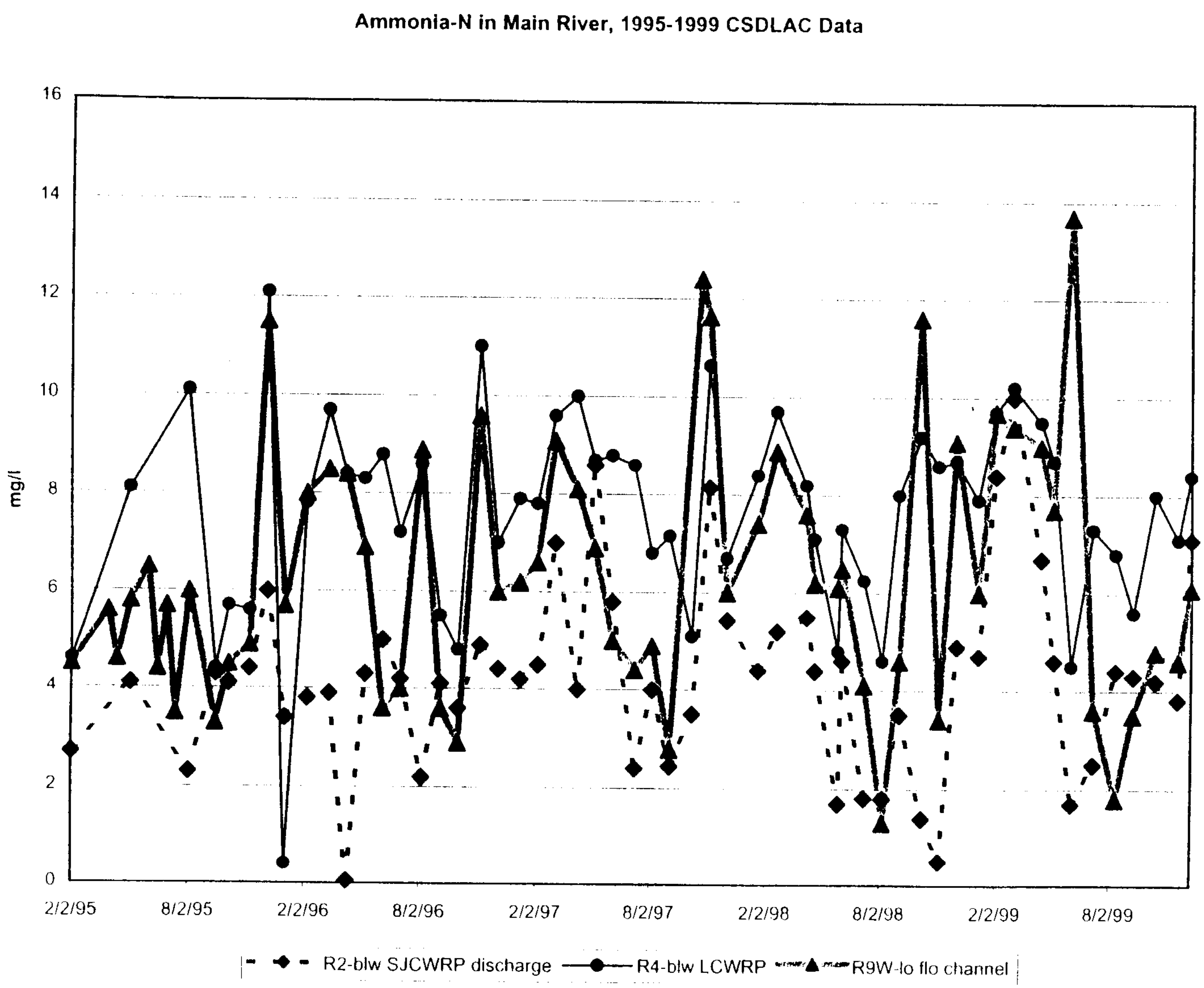

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Figure 10

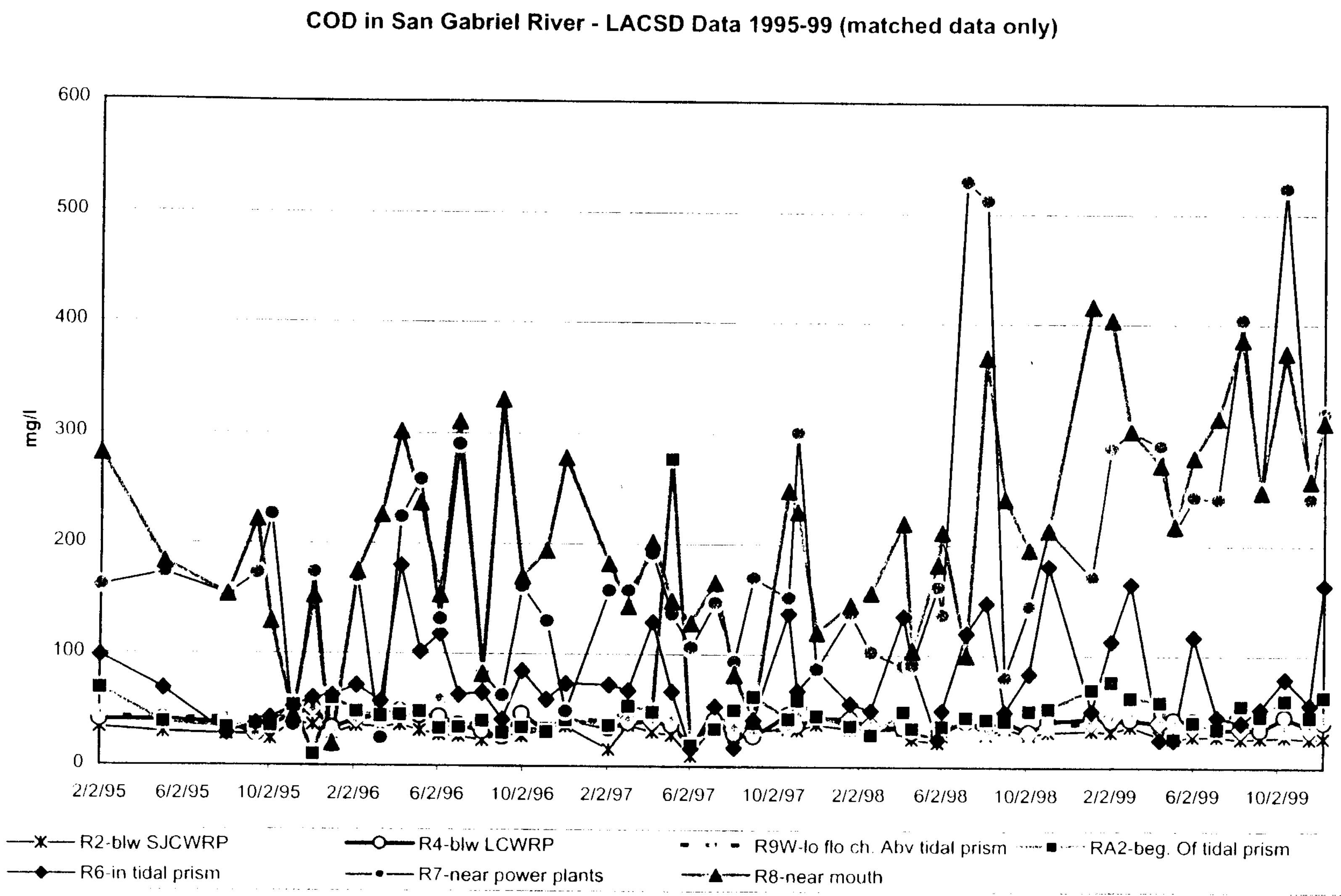

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Figure 11

COD in Coyote Creek - LACSD Data 1995-99

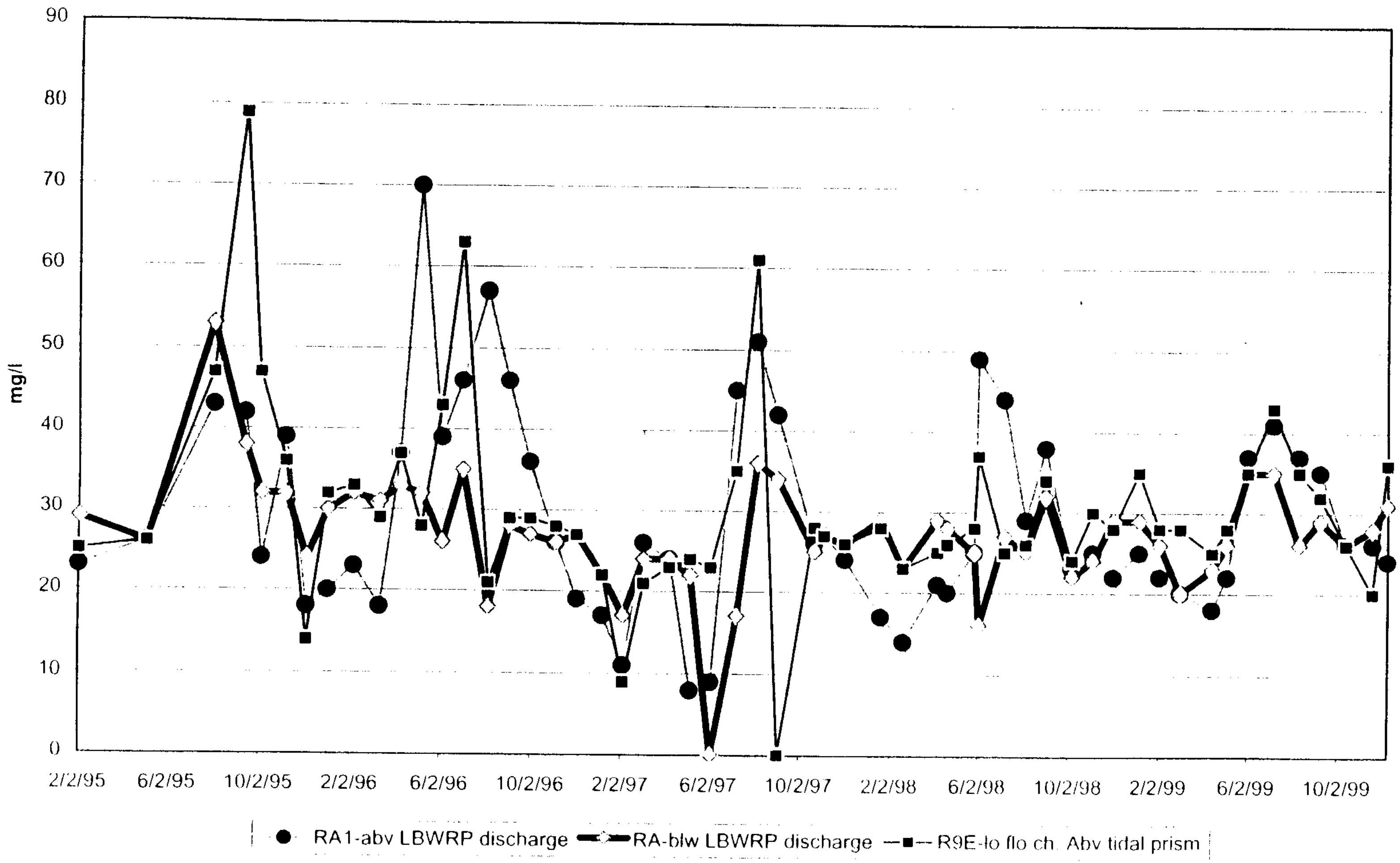

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Figure 12

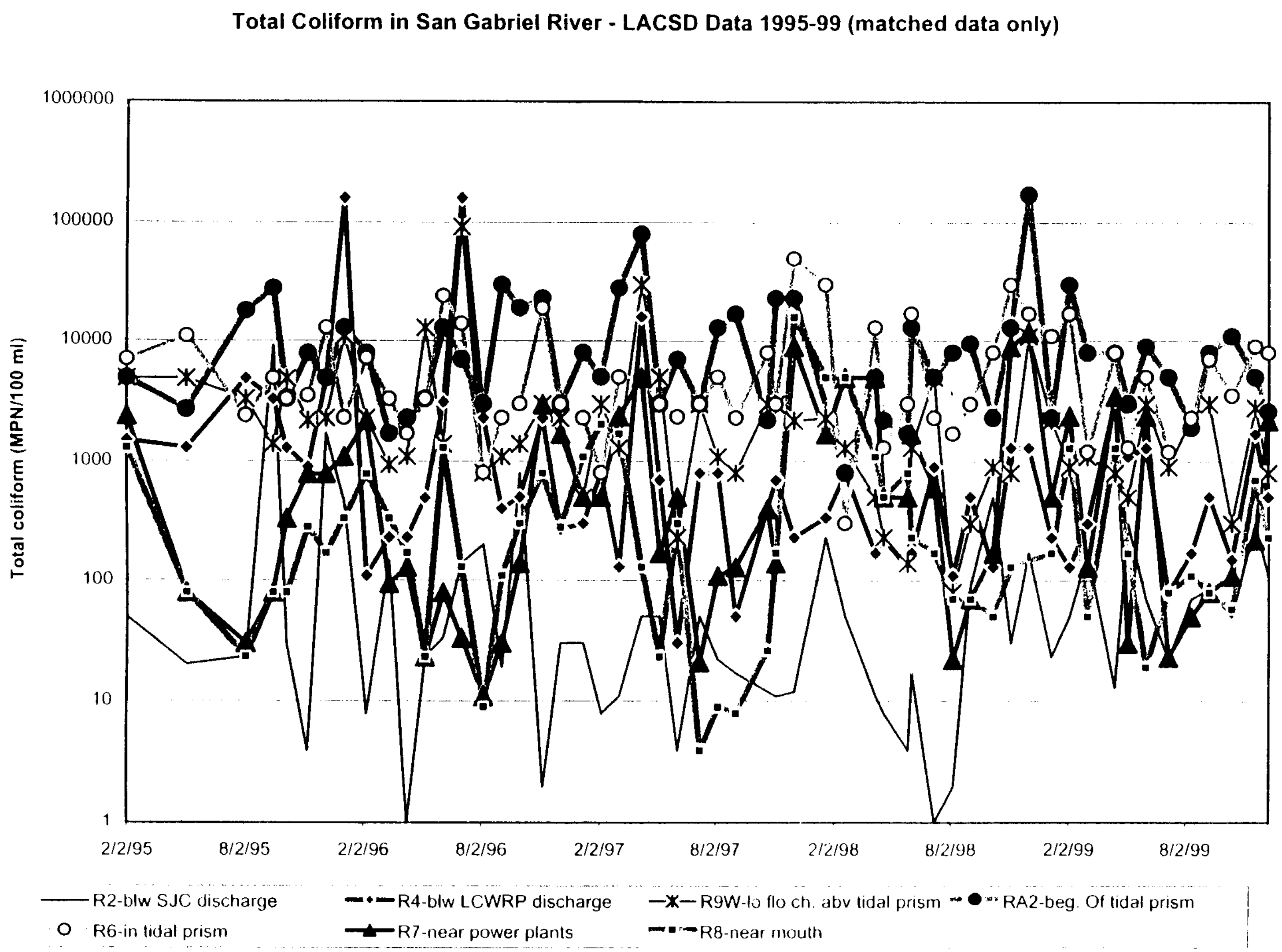

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Figure 13

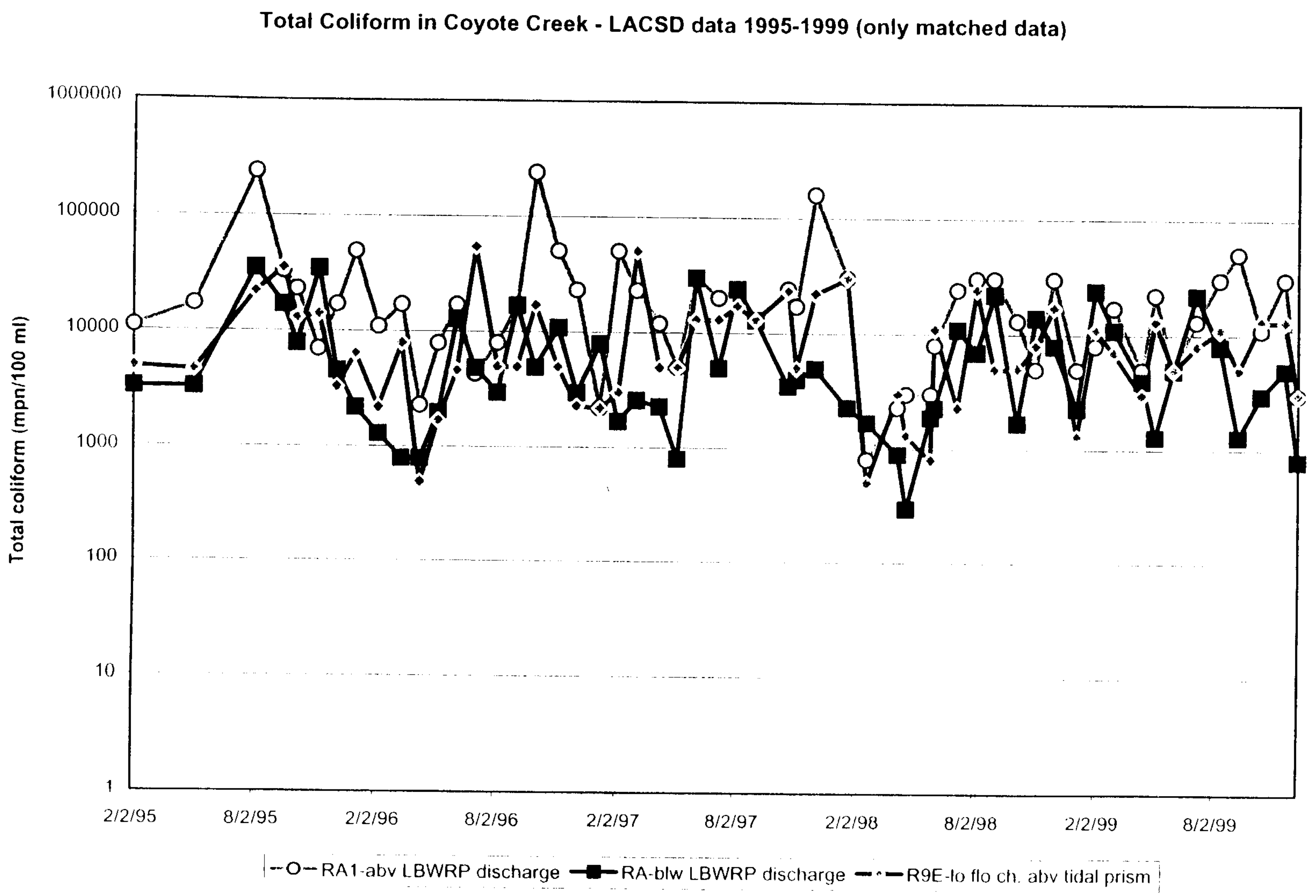

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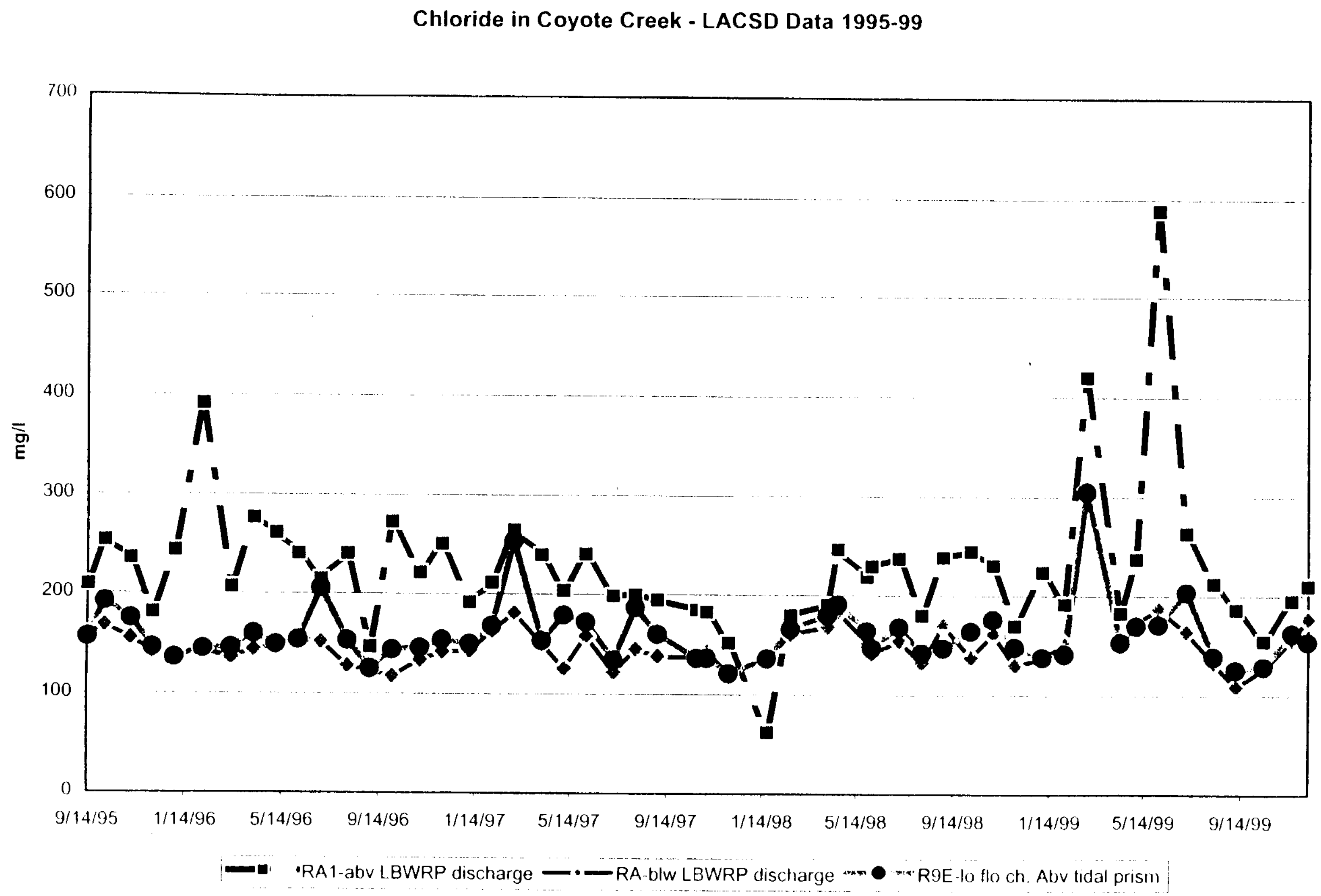
Figure 14



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Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data

By John R. Gray, G. Douglas Glysson, Lisa M. Turcios, and Gregory E. Schwarz

Water-Resources Investigations Report 00-4191

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August 2000

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CONTENTS

Abstract ....

Introduction 1

Field Techniques and Laboratory Methods 1

Field Techniques 2

Laboratory Methods 2

Suspended-Sediment Concentration Analytical Method 3

Total Suspended Solids Analytical Method 3

Differences Between the Suspended-Sediment Concentration and 3

Total Suspended Solids Analytical Methods ....

Description of Data Used in the Evaluation 4

Arizona 5

Hawaii 5

Illinois 5

Kentucky 5

Maryland 5

Virginia 5

Washington 6

Wisconsin 6

Quality-Control Data 6

Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data 6

Natural-Water Data 6

Quality-Control Data 6

Conclusions 10

References Cited 11

.... 12

List of Tables:

1. State in which natural-water samples were collected, collecting organization, collection methods, and devices for obtaining subsamples for suspended-sediment concentration and total suspended solids analyses 2
2. Statistical characteristics of paired suspended-sediment concentrations (SSC) and total suspended solids (TSS) data for each of eight States, and for the combined data from all States 7

List of Figures:

1. Bar graph showing number of paired suspended-sediment concentration values and total suspended solids values of the 3,235 data pairs for selected suspended-sediment concentration ranges 6
2. Scatter plot showing relation between untransformed values of suspended-sediment concentration and total suspended solids for 3,235 data points 7
3. Scatter plot showing relation between the base-10 logarithms of suspended-sediment concentration and total suspended solids for 3,235 data pairs in the scattergrams plotted 8
4. Scatter plots showing relation between the base-10 logarithms of suspended-sediment concentration and total suspended solids for the data pairs from each State used in the analysis 9
5. Scatter plot showing relation between percent sand-size material in the sample analyzed for suspended-sediment concentration and the remainder of suspended-sediment concentration minus total suspended solids 10
6. Scatter plot showing relation between total suspended solids and the concentration of suspended sediments finer than 0.062 mm in paired suspended-sediment concentration samples 10
7. Graph showing instantaneous water discharges and sediment discharges computed from total suspended solids and suspended-sediment concentration data for a stream in the northeastern United States, 1998 11
8. Boxplot showing variability in results of suspended-sediment concentrations and total suspended solids analytical methods in quality-control water samples analyzed by a cooperator laboratory 11

CONVERSION FACTORS

Multiply SI units	By	To obtain inch-pound units
	Length	
millimeter (mm)	0.03937	inch (in)
	Volume	
liter (L)	33.82	ounce fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
	Flow	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
gram (g)	0.002205	ounce, avoirdupois (oz)
megagram (Mg)	1.102	ton, short
	Temperature	
degree Celsius (°C)	F = 1.8 x°C + 32	degree Fahrenheit (°F)
	Concentration (Mass/Volume)	
milligrams per liter (mg/L)	1.0	parts per million (ppm[1])
milligrams per liter (mg/L)	0.0000334	ounces per quart (oz/qt)

[1]This conversion is true for concentration values <8,000 mg/L. The equivalent value in mg/L for concentrations ≥8,000 ppm can be calculated from table 1, American Society of Testing Material (2000), or by using the following equation:

$$C_{mg/L} = C_{ppm}/(1 - C_{ppm}(6.22 \times 10^{-7})$$

where:
$C_{mg/L}$ = sediment concentration, mg/L, and
C_{ppm} = sediment concentration, ppm

Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data

By John R. Gray, G. Douglas Glysson, Lisa M. Turcios, and Gregory E. Schwarz

ABSTRACT

Two laboratory analytical methods — suspended-sediment concentration (SSC) and total suspended solids (TSS) — are predominantly used to quantify concentrations of suspended solid-phase material in surface waters of the United States. The analytical methods differ. SSC data are produced by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture. TSS data are produced by several methods, most of which entail measuring the dry weight of sediment from a known volume of a subsample of the original. An evaluation of 3,235 paired SSC and TSS data, of which 860 SSC values include percentages of sand-size material, shows bias in the relation between SSC and TSS —SSC values tend to increase at a greater rate than their corresponding paired TSS values. As sand-size material in samples exceeds about a quarter of the sediment dry weight, SSC values tend to exceed their corresponding paired TSS values. TSS analyses of three sets of quality-control samples (35 samples) showed unexpectedly small sediment recoveries and relatively large variances in the TSS data. Two quality-control data sets (18 samples) that were analyzed for SSC showed both slightly deficient sediment recoveries, and variances that are characteristic of most other quality-control data compiled as part of the U.S. Geological Survey's National Sediment Laboratory Quality Assurance Program. The method for determining TSS, which was originally designed for analyses of wastewater samples, is shown to be fundamentally unreliable for the analysis of natural-water samples. In contrast, the method for determining SSC produces relatively reliable results for samples of natural water, regardless of the amount or percentage of sand-size material in the samples. SSC and TSS data collected from natural water are not comparable and should not be used interchangeably. The accuracy and comparability of suspended solid-phase concentrations of the Nation's natural waters would be greatly enhanced if all these data were produced by the SSC analytical method.

INTRODUCTION

The importance of fluvial sediment to the quality of aquatic and riparian systems is well established. The U.S. Environmental Protection Agency (1998) identifies sediment as the single most widespread cause of impairment of the Nation's rivers and streams, lakes, reservoirs, ponds, and estuaries.

Reliable, quality-assured sediment and ancillary data are the underpinnings for assessment and remediation of sediment-impaired waters. The U.S. Geological Survey (USGS) has protocols for the collection of sediment data (Edwards and Glysson, 1999) and for laboratory analysis of suspended-sediment samples (Guy, 1969; Matthes and others, 1991; Knott and others, 1992 and 1993; U.S. Geological Survey, 1998 and 1999a). Most of the laboratory analytical methods were adapted or developed by the Federal Interagency Sedimentation Project (1941), approved by the Technical Committee (Glysson and Gray, 1997), and used by most Federal agencies that analyze fluvial-sediment data.

Data collected, processed, and analyzed using consistent protocols are comparable in time and space. Conversely, data obtained using different protocols may not be comparable. The focus of this study is the comparability of suspended-sediment concentration (SSC) and total suspended solids (TSS) data. The terms SSC and TSS are often used interchangeably in the literature to describe the concentration of solid-phase material suspended in a water-sediment mixture, usually expressed in milligrams per liter (mg/L) (Gregory Granato, U.S. Geological Survey, oral commun., 1999; James, 1999). However, given that all other factors are held constant (such as particle density and shape), the analytical procedures for SSC and TSS differ and may produce considerably different results, particularly when sand-size material composes a substantial percentage of the sediment in the sample.

This report compares the SSC and TSS analytical methods and derivative data, and demonstrates which of the data types is the more accurate and reliable. The evaluation is based on historical SSC and TSS data collected and analyzed by the USGS and selected cooperators.

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Table 1. State in which natural-water samples were collected, collecting organization, collection methods, and devices for obtaining subsamples for suspended-sediment concentration (parameter code 80154) and total suspended solids (parameter code 00530) analyses
[SSC, suspended-sediment concentration; TSS, total suspended solids; USGS, U.S. Geological Survey]

State	Sample Collecting Organization		Sample Collection Method		Subsampling Device	
	SSC (80154)	TSS (00530)	SSC (80154)	TSS (00530)	SSC (80154)	TSS (00530)
Arizona[a]	USGS	USGS	USGS, 1999[i]	USGS, 1999[i]	Churn Splitter	Churn Splitter
Hawaii[b]	USGS	USGS	Automatic Sampler	Automatic Sampler	None	Churn Splitter
Illinois[c]	USGS	USGS	USGS, 1999[i], Open Bottle	USGS, 1999[i]	Churn Splitter	Churn Splitter
Kentucky[d]	USGS	USGS	USGS	Open Bottle	None	None
Maryland[e]	USGS	USGS	Open Bottle, USGS, 1999[i], Automatic Sampler	USGS, 1999[i], Automatic Sampler	Churn Splitter	Churn Splitter
Virginia[f]	USGS and Cooperator	USGS and Cooperator	USGS, 1999[i]	USGS, 1999[i]	None	Churn Splitter
Washington[g]	USGS	USGS	USGS, 1999[i]	USGS, 1999[i]	None	Churn Splitter
Wisconsin[h]	USGS	Cooperator	USGS, 1999[i]	Open Bottle	Cone Splitter	Cone Splitter

[a] James G. Brown, U.S. Geological Survey, written commun. (1999).
[b] Stephen S. Anthony, U.S. Geological Survey, written commun. (1999).
[c] Daniel J. Sullivan, U.S. Geological Survey, written commun. (1999).
[d] Ronald D. Evaldi, U.S. Geological Survey, written commun. (1999).
[e] Stephen D. Preston, U.S. Geological Survey, written commun. (1999).
[f] Donna L. Belval, U.S. Geological Survey, written commun. (1999).
[g] Richard J. Wagner, U.S. Geological Survey, written commun. (1999).
[h] Herbert S. Garn, U.S. Geological Survey, written commun. (1999).
[i] See Edwards and Glysson (1999).

FIELD TECHNIQUES AND LABORATORY METHODS

The paired SSC and TSS results used in this evaluation were derived from analyses of natural-water samples collected by the USGS and selected cooperators (table 1). Analyses of all SSC data from natural water were made by USGS sediment laboratories, and analyses of the TSS data were made by USGS and cooperating laboratories. Additionally, 53 quality-control samples were prepared by the USGS and analyzed by a laboratory that provides data to the USGS.

Field Techniques

The large majority of water samples were collected using either the equal-width-increment or the equal-discharge-increment method to obtain a composite sample that is representative of the discharge-weighted SSC (Edwards and Glysson, 1999). Some samples, including those obtained by at least one cooperating agency, were collected by dipping an open bottle to obtain samples for subsequent TSS analysis. Some of the paired SSC and TSS samples were collected in-stream sequentially and submitted to laboratories for analysis as whole samples. The remaining samples were split into subsamples by using a churn splitter or cone splitter (Ward and Haar, 1990; Capel and Larson, 1996; Capel and others, 1995).

Tests performed by the USGS demonstrate that the churn splitter and cone splitter can provide unbiased and acceptably precise (generally within 10 percent of the known value) SSC values as large as about 1,000 mg/L when the mean diameter of sediment particles is less than about 0.25 mm. At SSC values of 10,000 mg/L or more, the bias and precision of SSC values in churn splitter subsamples are considered unacceptable (U.S. Geological Survey, 1997; Wilde and others, 1999).

Cone splitters produce subsamples with SSC values that are adequately representative of the original sample at 10,000 mg/L, but not at 100,000 mg/L. The accuracy of the cone splitter for SSC values between 10,000 mg/L and 100,000 mg/L is unknown and is considered unacceptable at concentrations larger than 100,000 mg/L (U.S. Geological Survey, 1997; Wilde and others, 1999).

Subsampling will typically increase the variance and (or) create bias in the concentration and size distribution of solid-phase material in a subsample. Significant differences in the amount of solid-phase material in some paired samples may have occurred as a result of non-representative splitting of the original samples, or by collecting consecutive in-stream samples under conditions of rapidly varying SSC. Similarly, because the data were obtained by field personnel in eight States as part of unrelated studies, significant differences may have resulted because of differences in data-collection techniques. However, the probability of significant bias resulting from consistently selecting samples with larger concentrations of sediment for analyses by one of the methods would be small based on the large number of paired data used in the analysis. There is no evidence indicating that methods used for collecting, processing, or selecting subsamples for subsequent analysis introduced bias in the relations between SSC and TSS identified in this evaluation.

Laboratory Methods

Two standard methods are widely cited in the United States for determining the total amount of suspended material in a water sample. These are:

1. Method D 3977-97, "Standard Test Method for Determining Sediment Concentration in Water Samples" of the American Society for Testing and Materials (American Society for Testing and Materials, 2000), and
2. Method 2540 D, "Total Suspended Solids Dried at 103°–105° C" (American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1995).

The differences in these analytical methods, and some variations used to produce TSS data are described below.

Suspended-Sediment Concentration Analytical Method. ASTM Standard Test Method D 3977-97 lists three methods that result in a determination of SSC values in water and wastewater samples:

1. Test Method A – Evaporation: The evaporation method may only be used on sediment that settles within the allotted storage time, which can range from a few days to several months. If the dissolved-solids concentration exceeds about 10 percent of the SSC value, an appropriate correction factor must be applied to the SSC value. The precision and bias of Method A are shown as follows:

[mg/L, milligrams per liter]

Concentration Added, (mg/L)	Concentration Recovered, (mg/L)	Standard Deviation of Test Method (mg/L)	Standard Deviation of Single Operator (mg/L)	Bias, percent
10	9.4	2.5	2.3	-6
1,000	976	36.8	15.9	-2.4
100,000	100,294	532	360	0.3

2. Test Method B- Filtration: The filtration method is used only on samples with concentrations of sand-size material (diameters greater than 0.062 mm) less than about 10,000 mg/L and concentrations of clay-size material of about 200 mg/L. No dissolved-solids correction is needed. The precision and bias of Method B are shown as follows:

[mg/L, milligrams per liter]

Concentration Added, (mg/L)	Concentration Recovered, (mg/L)	Standard Deviation of Test Method (mg/L)	Standard Deviation of Single Operator (mg/L)	Bias, percent
10	8	2.6	2	-20
100	91	5.3	5.1	-9
1,000	961	20.4	14.1	-3.9

3. Test Method C - Wet-sieving filtration: The wet-sieve-filtration method also yields a SSC value, but the method is not as direct as Methods A and B. Method C is used if the percentage of material larger than sand-size particles is desired. The method yields a concentration for the total sample, a concentration of the sand-size particles, and a concentration for the silt- and clay-size particles. A dissolved-solids correction may be needed, depending on the type of analysis done on the fine fraction of the samples and the dissolved-solids concentration of the sample. The precision and bias of Method C are shown as follows:

[mm, millimeters; mg/L, milligrams per liter]

Mixture Number	Sieve Diameter (mm)	Concentration Added (mg/L)	Concentration Recovered (mg/L)	Standard Deviation of Test Method (mg/L)	Standard Deviation of Single Operator (mg/L)	Bias, percent
1	>0.062	1	3.4	2.8	2.4	240
1	<0.062	10	8.7	4.3	2.9	-13
2	>0.062	9	5	5.9	1.9	-44
2	<0.062	91	79	15.2	11	-13
3	>0.062	91	107	12.3	5.9	18
3	<0.062	909	832	87.2	61	-8

These three methods are virtually the same as those used by USGS sediment laboratories and described by Guy (1969). Only the Whatman grade 934AH, 24-mm-diameter filter is used for purposes of standardization. Each method includes retaining, drying at 103°C ±2°C, and weighing all of the sediment in a known mass of a water-sediment mixture (U.S. Geological Survey, 1999a).

Total Suspended Solids Analytical Method. According to the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1995), the TSS analytical method uses a predetermined volume from the original water sample obtained while the sample is being mixed with a magnetic stirrer. An aliquot of the sample — usually 0.1 L, but a smaller volume if more than 200 mg of residue may collect on the filter — is withdrawn by pipette. The aliquot is passed through a filter, the diameter of which usually ranges from 22 to 125 mm. The filter may be a Whatman grade 934AH, Gelman type A/E, Millipore type AP40; E-D Scientific Specialties grade 161, or another product that gives demonstrably equivalent results. After filtering, the filter and contents are removed and dried at 103° to 105° C, and weighed. No dissolved-solids correction is required. The percentages of sand-size and finer material cannot be determined using the TSS method.

The American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1995) describe the precision for this method as follows: "The standard deviation was 5.2 mg/L (coefficient of variation 33 percent) at 15 mg/L, 24 mg/L (10 percent) at 242 mg/L, and 13 mg/L (0.76 percent) at 1,707 mg/L in studies by two analysts of four sets of 10 determinations each. Single-laboratory analyses of 50 samples of water and wastewater were made with a standard deviation of differences of

2.8 mg/L." The standard provides no indication of the size of particles used in the testing for the method.

In practice, TSS data are produced by a number of variations to the processing methods described in the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1995). For example

- For the collection of TSS samples as part of the Chesapeake Bay Program, field staff pump water from a specified depth into a plastic gallon container. The container is vigorously shaken, and 0.2 – 1.0 L of the water-sediment mixture is poured for field filtering and subsequent analysis. (Mary Ley, Interstate Commission on the Potomac River Basin, the State of Maryland and the Commonwealth of Virginia, written commun., 2000).
- One State government laboratory produces TSS data by vigorously shaking the sample and pouring it into a crucible for subsequent analysis. All of the sample is poured into the crucible unless "there is a lot of suspended material," in which case only part of the sample is poured (Lori Sprague, U.S. Geological Survey, written commun., 1999).
- Another laboratory analyzed quality-control samples by using Method 2540D of the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1995), with the following variation: The sample is shaken vigorously and a third of the desired subsample volume is decanted to a secondary vessel. This process is repeated twice to obtain a single subsample for subsequent filtration, drying and weighing.

The reduction in TSS data comparability is not limited to lack of consistency in processing and analytical methods. According to James (1999), there is generally no agreed upon definition of TSS in regard to storm-water runoff, in part because the settleable part of TSS is not reported in most storm-water studies.

The problem extends to nomenclature. The terms "SSC" and "TSS", or variations thereof, are sometimes attributed to an incorrect data type. For example, a proposed Total Maximum Daily Load for sediment in Stekoa Creek, Georgia (U.S. Environmental Protection Agency, Region 4, written commun., 2000) is based on regional TSS data, which are compiled from U.S. Geological Survey records; the TSS data referred to are actually SSC data. Buchanan and Schoellhamer (1998) refer to "suspended-solids concentration data" for San Francisco Bay. Those data would more appropriately be referred to as SSC, because the total water-sediment mass and all sediment were measured in the analysis (Alan Mlodnosky, USGS, oral commun., 1999).

Part of the problem may be attributable to the origin of the TSS method and subsequent changes in the types of water for which it is recommended for use. Information available from the American Public Health Association and American Water Works Association (1946) makes it clear that the Suspended Solids Method was intended for use for wastewater effluents (Kenneth Pearsall, U.S. Geological Survey, written commun., 2000). This is more or less consistent with the Total Suspended Matter Method, which was "intended for use with wastewaters, effluents, and polluted waters," as listed in the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1971). A fundamental change took place in 1976, when the Total Suspended Matter Method was deemed suitable for "residue in potable, surface, and saline waters, as well as domestic and industrial wastewaters in the range up to 20,000 mg/L" by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1976). The Suspended Solids and Total Suspended Matter Methods described above are predecessors of the "Total Suspended Solids Dried at 103°-105°C" Method, which first appeared in 1985 by that title in the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1985).

In summary, the evidence indicates that the TSS method was originally designed for wastewater analyses, presumably on samples collected after a settling step at a wastewater treatment facility (hence the term "suspended" in TSS). The American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1976) expanded the TSS Method's applicability in 1976 to include natural water.

Differences Between the SSC and TSS Analytical Methods. The fundamental difference between the SSC and TSS analytical methods stems from preparation of the sample for subsequent filtering, drying, and weighing. A TSS analysis normally entails withdrawal of an aliquot of the original sample for subsequent analysis, although as previously noted, there is evidence of inconsistencies in methods used in the sample preparation phase of the TSS analyses. The SSC analytical method measures all sediment and the mass of the entire water-sediment mixture. Additionally, the percentage of sand-size and finer material can be determined as part of the SSC method, but not as part of the TSS method.

If a sample contains a substantial percentage of sand-size material, then stirring, shaking, or otherwise agitating the sample before obtaining a subsample will rarely produce an aliquot representative of the SSC and particle-size distribution of the original sample. This is a by-product of the rapid settling properties of sand-size material, compared to those for silt- and clay-size material, given virtually uniform densities and shapes as described by Stokes' Law. Aliquots obtained by pipette might be withdrawn from the lower part of the sample where the sand concentration tends to be enriched immediately after agitation, or from a higher part of the sample where the sand concentration is rapidly depleted.

The physical characteristics of a pipette used to withdraw an aliquot, or subsample, can introduce additional errors in subsequent analytical results. The American Public Health Association, American Water Works Association, and Water Pollution Control Federation (1995) specifies use of "wide-bore pipettes" to withdraw aliquots. The tip opening of those recommended for use is about 3 mm in diameter (Kimble-Contes Inc., accessed May 1, 2000). By definition, the upper limit of sand-size material, which is expressed as the median diameter, is 2 mm (Folk, 1980). A natural sediment particle's long axis is almost always larger than its median axis and can be substantially larger. Hence, a single coarse-grained sand particle or multiple sand-size particles, particularly when present in large concentrations, may clog a 3-mm tip pipette under suction.

If the aforementioned lack of consistency in the TSS analytical procedure extends to variability in diameters of pipette tips used to withdraw TSS aliquots, the size of particles being excluded from the subsample could vary with the type of pipette used. Hence, use of a pipette may cause concentration bias when subsampling if sand-size material is present in the sample.

Based on Stokes' Law, subsamples obtained by pouring sand-rich water-sediment mixtures should be deficient in sand-size material. Because the fine material concentration will not normally be altered by the removal of an aliquot, the differences between the two methods will tend to be more pronounced as the percentage of sand-size material in the sample increases.

Samples collected sequentially in-stream may have different concentrations and size characteristics of solid-phase material. This may be due to natural variations in the amounts and composition of solid-phase material in transport, and to variance and (or) bias that is introduced by sampling procedures. Likewise, a subsample may contain an amount and size distribution of sediment atypical to that of the original. However, any differences in SSC and size-distribution data from paired samples resulting from in-stream variations or sampling procedures would likely occur randomly among the 3,235 paired analyses used in this evaluation.

DESCRIPTION OF DATA USED IN THE EVALUATION

Results of analyses of natural-water samples and of quality-control samples prepared by the USGS were used for this evaluation. Natural-water samples for determination of SSC (parameter code 80154) were collected and analyzed by the USGS (table 1). Natural-water samples for determination of TSS, (parameter code 00530) were collected by the USGS and cooperating agencies, and analyzed by the USGS and cooperating laboratories. A total of 3,235 pairs of SSC and TSS data for natural water were obtained from the files of USGS District offices.

The paired SSC and TSS data were collected at 65 sampling sites in Arizona, Hawaii, Illinois, Kentucky, Maryland, Virginia, Washington, and Wisconsin. All but the 12 sampling sites in Kentucky were at USGS streamflow-gaging stations. The percentage of sand-size material was available for 860, or about 27 percent, of the SSC samples. The SSC and TSS natural-water data used in this evaluation were augmented by analytical results of 53 quality-control samples prepared by the USGS National Sediment Laboratory Quality Assurance Program (Gordon and others, 2000, U.S. Geological Survey, 1998; 1999a; 1999b; 2000b).

Arizona. A total of 122 SSC and TSS sample pairs were collected at a USGS streamflow-gaging station on Pinal Creek at Inspiration Dam near Globe (station number 09498400) in central Arizona from 1982-98. The samples were collected about monthly or bimonthly using techniques described by Edwards and Glysson (1999). A churn splitter was used to obtain subsamples of the water-sediment mixture. The USGS sediment laboratory in Iowa City, Iowa, analyzed the subsamples for SSC and TSS (James G. Brown, U.S. Geological Survey, written commun., 1999).

Hawaii. According to Hill (1996), 13 SSC and TSS sample pairs were collected at three streamflow-gaging stations in the Kamooalii drainage basin, Oahu, Hawaii, from 1985-89, as a component of a large-scale highway-construction study. The SSC samples were collected by a US PS-69 automatic pumping sampler. The TSS samples were collected by a Manning automatic pumping sampler. A churn splitter was used to obtain subsamples for TSS analyses. The SSC samples were analyzed by the USGS sediment laboratory in Oahu. The TSS samples were analyzed by the USGS National Water Quality Laboratory in Denver, Colorado (Stephen S. Anthony, U.S. Geological Survey, written commun., 1999).

Illinois. A total of 223 SSC and TSS sample pairs were collected at 8 USGS streamflow-gaging stations in the upper Illinois River Basin from 1988-90 (Sullivan and Blanchard, 1994). Samples were collected according to techniques described by Edwards and Glysson (1999). A churn splitter was used to obtain subsamples for SSC and TSS analyses. SSC samples were analyzed at the USGS sediment laboratory in Iowa City, Iowa, using the evaporation method. TSS samples were analyzed by an Illinois State laboratory using the nonfilterable residue, gravimetric method (Daniel Sullivan, U.S. Geological Survey, written commun., 1999).

Kentucky. A total of 95 SSC and TSS sample pairs were collected at 12 sampling locations in the Ohio River Basin in May 1999. SSC and TSS samples were collected at each site for one day over several hours at about 1-hour intervals. Samples were collected using an open-bottle sampler because of the low stream velocities. No splitting devices were used to obtain subsamples. The USGS sediment laboratory in Louisville, Kentucky, analyzed the SSC samples. A contract laboratory performed the TSS analyses (Ronald Evaldi, U.S. Geological Survey, written commun., 1999).

Maryland. A total of 1,561 SSC and TSS sample pairs were collected at 6 streamflow-gaging stations in the Patuxent River Basin, Maryland, as part of the USGS Patuxent Nonpoint Source study during the years 1985-98 (Preston and Summers, 1997). The sampling frequency was monthly, with additional samples collected during periods of storm runoff. The monthly base-flow samples were collected using the equal-width-increment method (Edwards and Glysson, 1999), and the storm-runoff samples were collected using an automatic sampler. A churn splitter was used for both monthly and storm samples of both SSC and TSS. The SSC samples were analyzed at USGS sediment laboratories in Lemoyne, Pennsylvania, and Louisville, Kentucky. The TSS samples were analyzed using a pipette and filtration method by a Maryland State laboratory (Stephen D. Preston, U.S. Geological Survey, written commun., 1999).

Virginia. A total of 188 SSC and TSS sample pairs were collected at 7 streamflow-gaging stations in Virginia during the years 1975-95. Paired SSC and TSS samples were collected every other month by the USGS except during some low-flow periods as part of the River Input Monitoring Program (U.S. Geological Survey, 2000a). Techniques described by Edwards and Glysson (1999) were used to collect all samples. A churn splitter was used to obtain subsamples for TSS analyses. The USGS collected most of the samples, except during some low-flow periods when the Virginia Department of Environmental Quality collected the samples. SSC analyses were performed by USGS sediment laboratories. A Virginia State laboratory performed the TSS analyses (Donna L. Belval, U.S. Geological Survey, written commun., 1999).

Washington. A total of 817 SSC and TSS sample pairs were collected at 25 streamflow-gaging stations in Washington during the years 1973-98, as part of various projects. Techniques described by Edwards and Glysson (1999) were used to collect all SSC and TSS samples. A churn splitter was used to obtain subsamples for TSS analyses. The SSC and TSS samples were analyzed at a USGS sediment laboratory in Tacoma, Washington, through September 1982. Thereafter, samples were analyzed at the USGS Cascades Volcano Observatory Sediment Laboratory (Richard J. Wagner, U.S. Geological Survey, written commun., 1999).

Wisconsin. A total of 216 SSC and TSS sample pairs were collected at 3 streamflow-gaging stations on streams in the Lake Michigan watershed, Wisconsin, as part of an evaluation of the differences in results of water-quality monitoring caused by differences in sample-collection methods (Kammerer and others, 1998). Low-flow samples were collected in August and October 1993, and high-flow samples were collected in April-July 1994. The SSC samples were collected using techniques described by Edwards and Glysson (1999). The TSS samples were collected concurrently with the SSC samples by the Wisconsin Department of Natural Resources using an open bottle. Subsamples for SSC and TSS analyses were obtained using a cone splitter. SSC samples were analyzed by the USGS sediment laboratory in Iowa City, Iowa. TSS samples were analyzed by a Wisconsin State laboratory (Herbert S. Garn, U.S. Geological Survey, written commun., 1999).

Quality-Control Data. The SSC and TSS natural-water data used in this evaluation were augmented by analytical results of quality-control samples from a cooperating laboratory. Known amounts of water and sediment were used to constitute quality-control samples as part of the USGS National Sediment Laboratory Quality Assurance Program. The National Sediment Laboratory Quality Assurance Program is designed as an interlaboratory-comparison evaluation to provide a measure of bias and variance of suspended-sediment data analyzed by laboratories operated or used by the USGS. The quality-control samples received by the participating laboratories were identified as such.

The quality-control samples were submitted in five batches to a cooperating laboratory during 1997-99. Of the quality-control samples, the first 35 were shipped as batch numbers 1997-1, 1997-2, and 1998-1 and were analyzed for TSS. Eighteen quality-control samples were shipped as batch numbers 1998-2 and 1999-1 and analyzed for SSC using the evaporation method (Kenneth Pearsall, U.S. Geological Survey, 1999, oral commun.).

COMPARABILITY OF SUSPENDED-SEDIMENT CONCENTRATION AND TOTAL SUSPENDED SOLIDS DATA

Natural-Water Data

The relation between SSC and TSS data was evaluated by comparing all available paired SSC and TSS natural-water data, and subsets of those data for each State. The number of paired SSC and TSS values for selected SSC concentration ranges with and without particle-size data are shown in figure 1.

Of the 3,235 natural-water SSC samples used in this study,

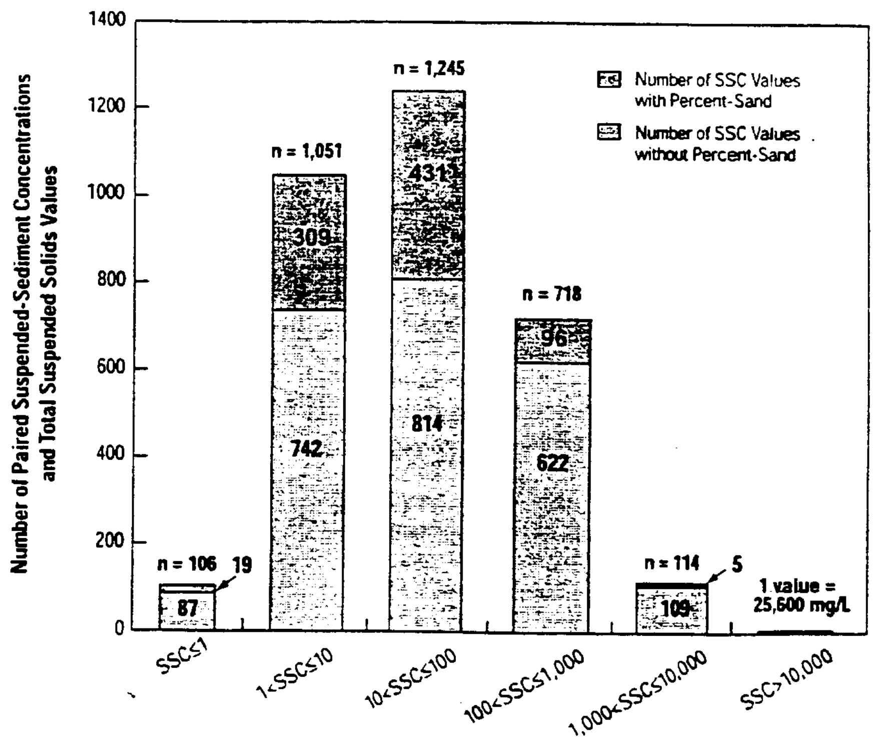

Figure 1. Number of paired suspended-sediment concentration (SSC) values and total suspended solids (TSS) values of the 3,235 data pairs for selected suspended-sediment concentration ranges, in milligrams per liter.

Table 2. Statistical characteristics of paired suspended-sediment concentration (SSC) and total suspended solids (TSS) data for each of eight States, and for the combined data from all States
[mg/L, milligrams per liter; >, greater than]

	SSC Values		SSC Minus TSS				
Source of SSC and TSS Paired Data	Number of values	3rd Quartile mg/L	Number of values >0 mg/L	Percentage of values >0 mg/L for all paired data	Number of values when SSC value is > 3rd Quartile value	Number of values >0 mg/L when SSC value is > 3rd Quartile value	Percentage of values >0 mg/L when SSC value is > 3rd Quartile value
Arizona	122	153.25	93	76%	31	30	97%
Hawaii	13	353.0	13	100%	3	3	100%
Illinois	223	48.5	111	50%	56	34	61%
Kentucky	95	10.2	28	29%	24	9	38%
Maryland	1,561	324.0	1,071	69%	390	328	84%
Virginia	188	16.0	105	56%	44	40	91%
Washington	817	30.0	518	63%	203	179	88%
Wisconsin	216	80.25	184	85%	54	54	100%
All Paired Data[1]	3,235	108.0	2,123	66%	809	672	83%

[1] Based on statistics using all 3,235 paired data; some values vary slightly from those calculated using summary statistics from the eight States.

74 percent had values less than or equal to 100 mg/L; only one value (25,600 mg/L) exceeded 10,000 mg/L (figure 1).

Statistical characteristics of SSC and TSS paired data for each State and for all paired data are given in table 2. Sixty-six percent of all TSS values are smaller than their corresponding paired SSC values. Eighty-three percent of all TSS values are smaller than their paired SSC value when SSC values exceed the 3rd quartile value. For each State except Kentucky (38 percent for 24 paired samples), 61 to 100 percent of the TSS values are smaller than their paired SSC value when SSC values exceed the 3rd quartile value. To summarize, SSC values tend to exceed their corresponding paired TSS values. This tendency becomes stronger at larger values of SSC.

Relations between all 3,235 paired TSS and SSC measurements are shown in figures 2 and 3. According to Glysson and others (2000), there is no simple, straightforward way to adjust TSS data to estimate SSC if paired samples are not available. Relations identified herein are not recommended for use in adjusting TSS data unless supported by additional research.

The data shown in figure 2 are plotted without transformation and include the two ordinary least squares regression lines obtained by regressing TSS on SSC (the lower line) and SSC on TSS (the upper line). Because of measurement errors associated with the collection processing, and analysis of the data, neither line can be interpreted as an unbiased estimate of the true relation

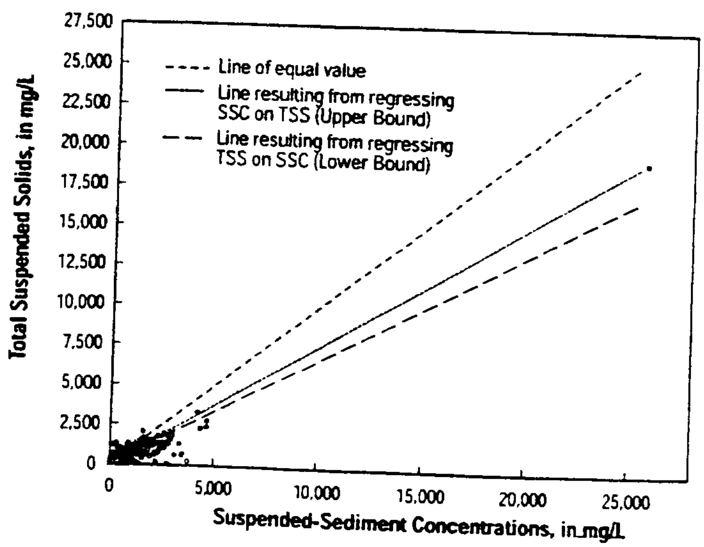

Figure 2. Relation between untransformed values of suspended-sediment concentration and total suspended solids for 3,235 data points.

between the two measurement methods. In fact, the existence of measurement error implies the system of equations describing the two measurements is insufficiently identified, making estimation of an unbiased relation impossible without additional information on the variance of the measurement error for at least one of the measurements (Klepper and Leamer, 1984). However, the two least squares regression lines can be used to bound the true slope and intercept coefficients (Frisch, 1934). In the case of TSS and SSC, the least squares intercepts are very small relative to the range of the data. Consequently, the two regression lines effectively form consistent upper and lower bounds on the true relation between TSS and SSC. These bounds imply that TSS is biased downward relative to SSC by a proportionate amount of 25 to 34 percent. Given the large skew apparent in the data, this finding is tentative and requires confirmation using a statistical or functional transformation yielding homoscedastic residuals.

The relation between SSC and TSS for all 3,235 pairs of transformed data using the base-10 logarithm and the line of equal value are shown in figure 3; the relations for each State and lines of equal value are shown in figure 4. Trends in the scattergrams plotted for all data compared to those with data that were segregated by State show some similarities, including a tendency for the data to plot to the right of the line of equal value, particularly at larger values of SSC.

As described previously, at least two factors associated with the TSS analysis can result in subsamples obtained by pipette or by pouring that are deficient in sand-size material. Rapidly falling sand-size material can be difficult to withdraw representatively, particularly if pipette subsamples are obtained from near the surface and (or) if the subsample is not withdrawn immediately after mixing. Also, coarser sand particles may plug the pipette intake, precluding withdrawal of a representative mixture. Subsamples obtained by pouring are also unlikely to contain representative amounts of sand-size material. In contrast, the amount or percentage of sand-size material in a SSC sample has no effect in bias because all sediment in the original sample is used in the SSC analysis.

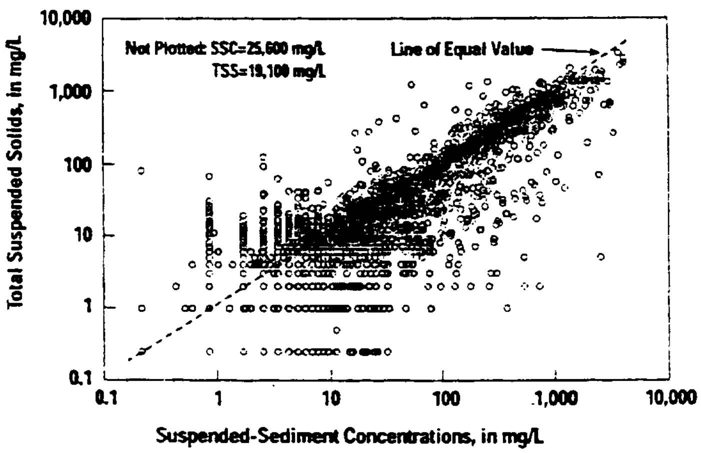

Figure 3. Relation between the base-10 logarithms of suspended-sediment concentration (SSC) and total suspended solids (TSS) for 3,235 data pairs in the scattergrams plotted. All SSC and TSS values less than 0.25 mg/L were set equal to 0.25 mg/L to enable plotting the data on logarithmic coordinates.

The relation between sand-size material and TSS bias was examined using the 860 paired SSC and TSS values for which the amounts of material coarser and finer than 0.062 mm in the SSC sample are known. Percent sand-size material, percent finer material, and the total mass of sand-size material were included in the analysis. All but one of the paired data associated with particle sizes are for streams in Illinois, Virginia, and Washington.

The relation between percent sand-size material associated with the SSC sample, and the SSC minus TSS remainder is shown in figure 5. No bias is apparent when sand-size material composes less than about a quarter of the sample's sediment mass. Above about a third sand-size material, the large majority of the SSC values exceed their paired TSS values. The increase in bias at larger SSC values as percent sand-size values increase is consistent with the observation that splitting original samples that contain a substantial percentage of sand-size material will rarely produce subsamples with a SSC or particle-size distribution similar to those of the original.

Splitting samples that contain small percentages of sand-size material are more likely to produce subsamples with concentrations and particle-size distributions similar to the original. The relation between TSS and the concentration of material finer than 0.062 mm for 860 of the paired SSC and TSS data with associated particle-size distribution data is shown in figure 6. The concentration of fine material was calculated as follows:

$$C_{<0.062mm} = SSC\,[1 - (Percent_{\geq 0.062mm}/100)]$$

$C_{<0.062mm}$ is the concentration of material finer than 0.062 mm in diameter,

SSC is suspended-sediment concentration, and

$Percent_{\geq 0.062mm}$ is percent sand-size material associated with the SSC value.

At TSS values that exceed about 5 mg/L of fine material, the SSC and TSS data are more or less evenly distributed around the line of equal value (figure 6). This suggests that the TSS method can provide relatively unbiased results when the large majority of material in a sample is finer than 0.062 mm.

The importance of bias in the relation between SSC and TSS characterized in figure 3 can be magnified when TSS data are used to compute sediment discharges. Sediment discharges increase when the product of water discharge and SSC increases (Porterfield, 1972). Additionally, the mobility of coarse material tends to increase with larger flow velocities. Because of the strong tendency for SSC to exceed TSS at larger values of SSC (see figures 3 and 4), calculating discharges of TSS will usually result in underestimates of

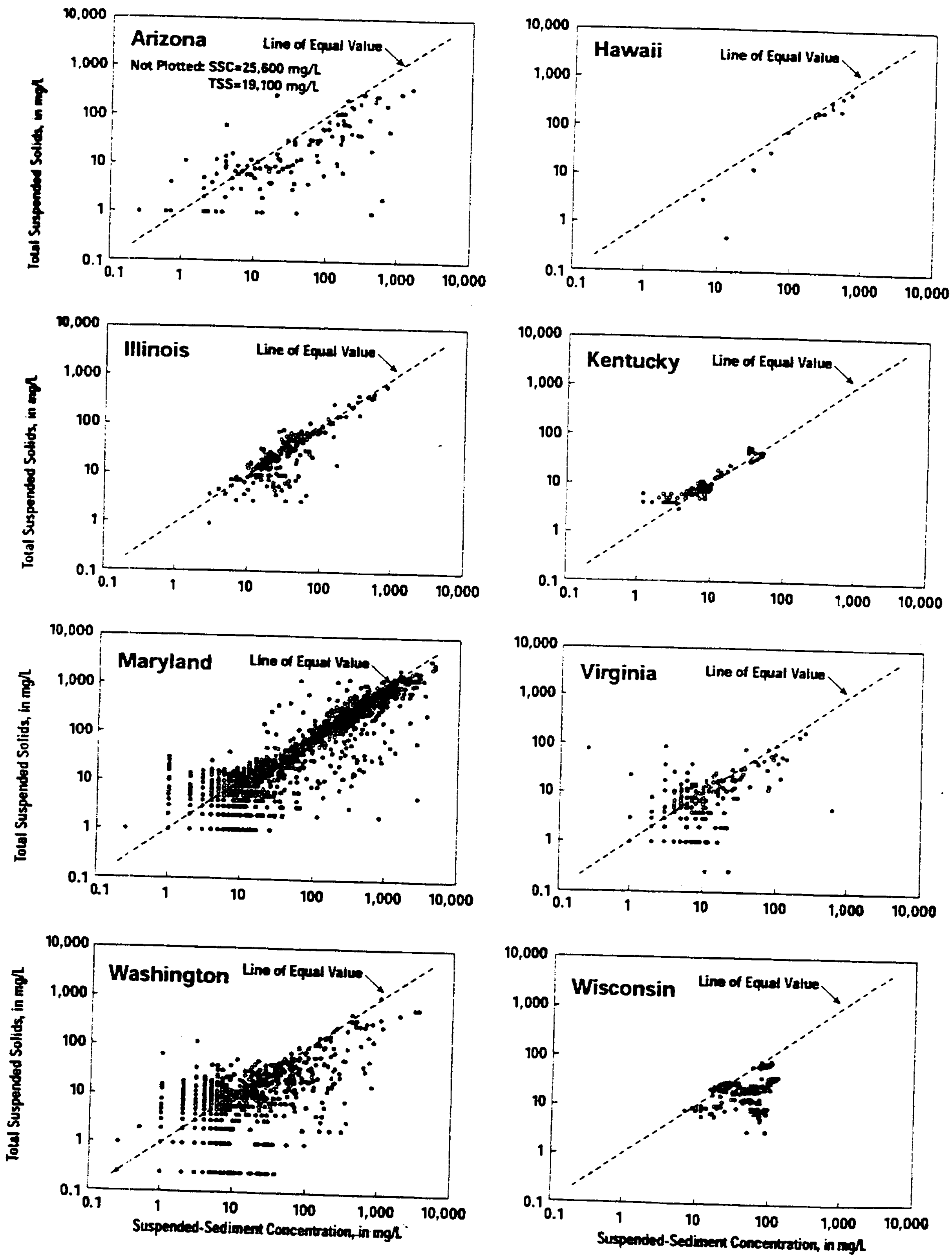

Figure 4. Relation between the base-10 logarithms of suspended-sediment concentration (SSC) and total suspended solids (TSS) for the data pairs from each State used in the analysis. All SSC and TSS values less than 0.25 mg/L were set equal to 0.25 mg/L to enable plotting the data on logarithmic coordinates.

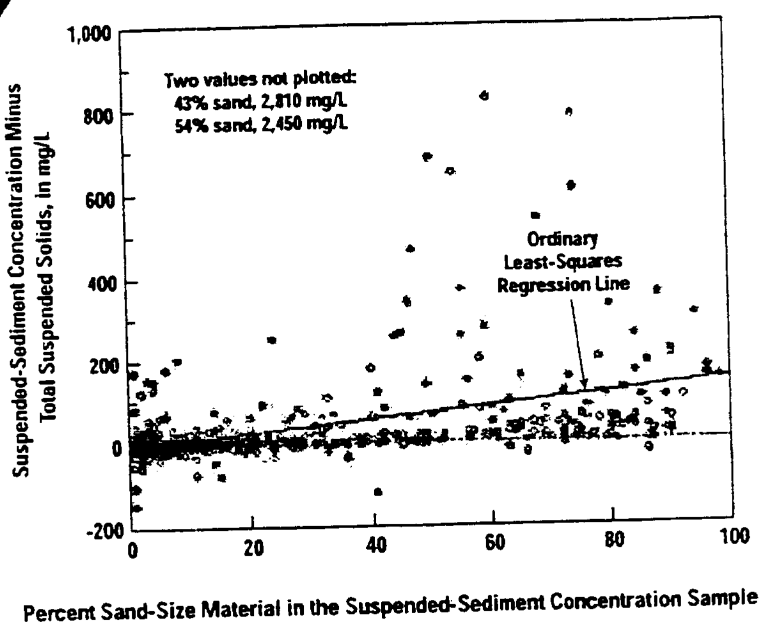

Figure 5. Relation between percent sand-size material in the sample analyzed for suspended-sediment concentration and the remainder of suspended-sediment concentration minus total suspended solids.

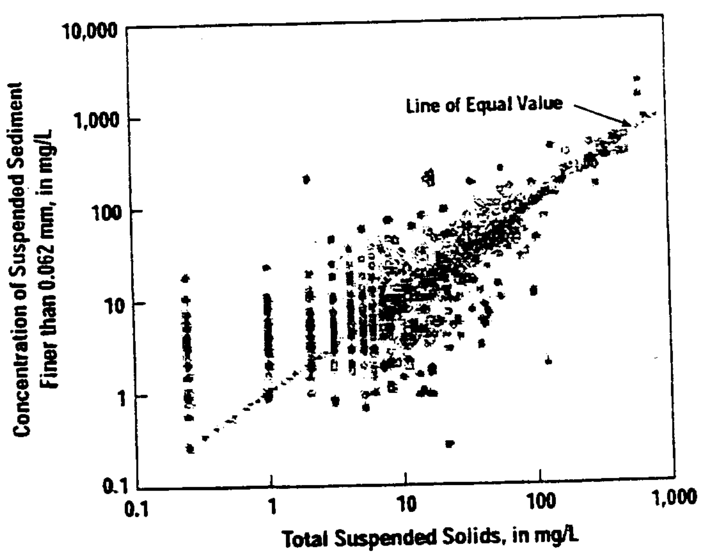

Figure 6. Relationship between total suspended solids and the concentration of suspended sediments finer than 0.062mm in paired suspended-sediment concentration samples. All SSC and TSS values less than 0.25 mg/L were set equal to 0.25 mg/L to enable plotting the data on logarithmic coordinates.

the suspended solid-phase discharges compared to those estimates that are computed from SSC data. TSS discharge underestimates may be negligible for streams conveying a predominantly fine material load over the range of discharges. Substantial underestimates of TSS discharges can be expected for streams conveying sediment loads that exceed about a third sand-size material in composition, and with percentages and concentrations of sand-size material that increase with discharge.

Figure 7 shows an example of the influence of bias resulting from using TSS data to calculate instantaneous sediment discharges for a stream in the northeastern United States. All the TSS and SSC samples used to compute sediment discharges from October 15 through December 24, 1998 were collected by a cooperating agency using an open bottle and analyzed by the cooperator's laboratory. The apparent order-of-magnitude change in sediment discharges between November and December 1998 was not related to any instream change in solid-phase transport, but to a change in analytical procedures (Henry Zajd, Jr., U.S. Geological Survey, oral commun., 2000). TSS analyses were performed on all samples collected in October and November 1998, and SSC analyses were used to produce subsequent data. The USGS did not publish daily sediment discharges for the pre-December period shown in figure 7 because the TSS data used in the computations were considered unreliable.

Quality-Control Data

Box plots that show the results of quality-control samples analyzed for SSC and TSS by a cooperating laboratory participating in the USGS National Sediment Laboratory Quality Assurance Program are shown in figure 8. The samples were analyzed in five sample sets. Box plots for sample sets 1997-1, 1997-2, and 1998-1 represent TSS analytical results. Box plots for study sample sets 1998-2 and 1999-1 represent SSC analytical results. This figure illustrates two important characteristics related to sediment-data quality.

First, both the SSC and TSS data tend to be negatively biased. The combined data for all samples analyzed as part of the Sediment Laboratory Quality Assurance Program from 1996 through September 2000 have a median concentration bias of -1.83 percent; the 25th percentile is -4.39 percent; and the 75th percentile is 0.00 percent. The bias primarily reflects a loss of some sediment, such as through a filter, or an inability to weigh accurately very small amounts of fine material in the SSC analytical procedure. The SSC median percent bias values for both study sets are about -2 and -4 percent of the known sediment mass. In contrast, TSS median percent bias values for the three study sets range from -6 to -23 percent from the known sediment mass; the mean difference in TSS median percent bias from the known sediment mass is -16 percent. Only for sample set 1997-2 does any quartile include the TSS value for the known sediment mass. The median percent bias in TSS sample set 1997-1 and in 1998-1 exceeds three F-pseudosigmas[2] from the mean value of all measured sediment mass measurements reported in the USGS National

[2]The F-pseudosigma is a nonparametric statistic analogous to the standard deviation that is calculated by using the 25th and 75th percentiles in a data set. It is resistant to the effect of extreme outliers.

Sediment Laboratory Quality Assurance Program. The analytical method used by the laboratory for determination of TSS in natural-water samples was deemed unacceptable by the U.S. Geological Survey (USGS, 1999b).

Second, the variances associated with the TSS quality-control data are large compared to those for SSC data (figure 8). The least variable data – those from sample set 1997-1 – range from -18 to -32 percent of the known value, and the difference between the 1st and 3rd quartile values is 9 percent. In comparison, the most variable SSC data – those from sample set 1999-1 – range from 0 to -5 percent; the difference in the 1st and 3rd quantile values is 4 percent.

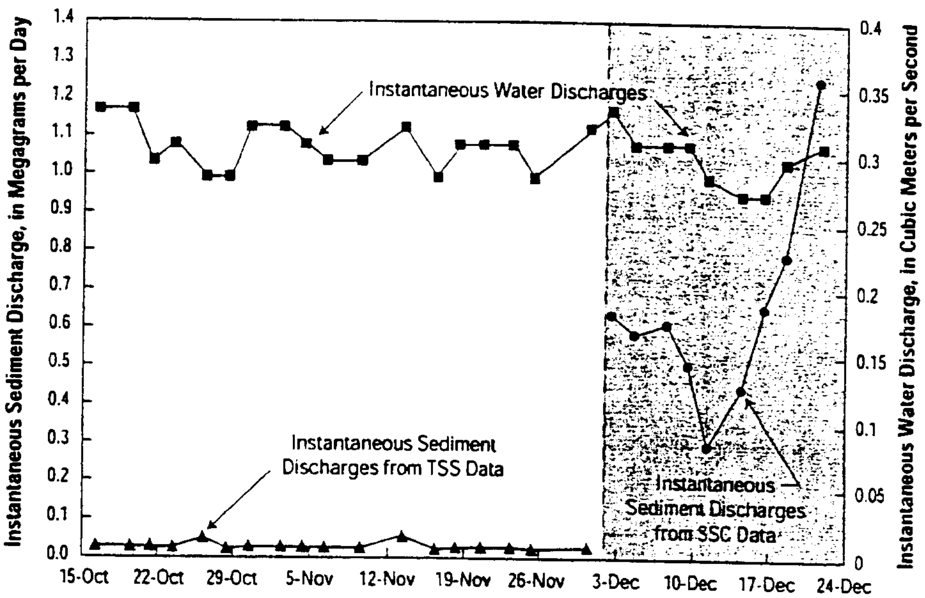

Figure 7. Instantaneous water discharges, and sediment discharges computed from total suspended solids (TSS) and suspended-sediment concentration (SSC) data for a stream in the northeastern United States, 1998.

In terms of bias and variance, the TSS results from two of the first three sample sets – 1997-1 and 1998-1 – were considered unacceptable by the U.S. Geological Survey (U.S. Geological Survey, 1998; 1999a). The SSC results from study sample sets 1998-2 and 1999-1, which were produced by the same laboratory, are considered among the most accurate of all laboratories that participated in the USGS National Sediment Laboratory Quality Assessment Program (John Gordon, U.S. Geological Survey, oral commun., 2000).

CONCLUSIONS

Of the two analytical methods examined for measuring the mass of solid-phase material in natural-water samples — suspended-sediment concentrations (SSC), and total suspended solids (TSS), — data produced by the SSC technique are the more reliable. This is particularly true when the amount of sand in a sample exceeds about a quarter of the dry sediment mass. This conclusion is based on the following observations:

1. The SSC analytical procedure entails measurement of the entire mass of sediment and the net weight for the entire sample. In contrast, only a part of the water-sediment mixture is typically used in the TSS analysis. Difficulties in, and variations for methods associated with obtaining TSS subsamples can result in determinations of solid-phase characteristics that are substantially different from those of the original sample.

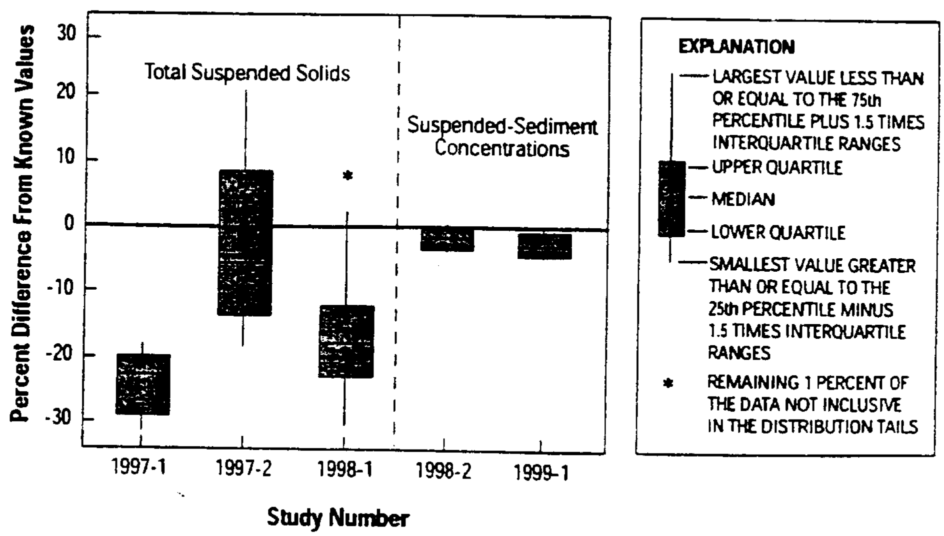

Figure 8. Variability in results of suspended-sediment concentrations and total suspended solids analytical methods in quality-control water samples analyzed by a cooperator laboratory. (John D. Gordon, U.S. Geological Survey, written commun., 2000).

2. Subsampling by pipette or by pouring from an open container will generally result in production of a sediment-deficient subsample. An analysis of 3,235 paired SSC and TSS natural-water samples from eight States showed that SSC values tend to exceed their paired TSS values, particularly at larger values of SSC. This is consistent with the assumption that most subsamples used to determine the TSS data were obtained by pipette or by pouring from an open container.

3. An analysis of 860 paired SSC and TSS natural-water samples for which relative amounts of sand-size and finer material are known for the SSC sample were used to determine the effect of sand-size particles on the TSS analysis. SSC values tend to be larger than their paired TSS values as the percentage of sand-size material exceeds about a quarter of the mass of sediment in the sample. Additionally, a relation between values of TSS and the paired SSC material finer than 0.062 mm showed that for samples with TSS values exceeding about 5 mg/L, the paired SSC and TSS data are more or less evenly distributed around the line of equal value. Sand-size material is more difficult to subsample than finer material due to the large fall velocity of sand-size material as described by Stokes' Law.

The tendency for SSC values to exceed their paired TSS values has important ramifications for computations of suspended solid-phase discharges; those computed using TSS data will often underestimate solid-phase discharges. This is particularly true for sites when the percentages of sand-size material in the water samples exceed about a third and where concentrations and percentages of sand-size material in transport increase with flow.

4. Fifty-three quality-control samples from a cooperator's laboratory — three sample sets totaling 35 TSS analyses of subsamples obtained by pouring from original samples, and two sample sets totaling 18 SSC analyses — were used to compare bias and variance introduced by use of the TSS and SSC analytical methods. Two of the three sample sets analyzed for TSS had unacceptably large mean negative bias. Variances associated with all three TSS sample sets were at least double those associated with the SSC quality-control results from the same laboratory. The two SSC sample sets analyzed by the same laboratory had small variances compared with those for the three TSS sample sets. The slight negative bias values associated with the SSC sample sets were consistent with data analyzed by most laboratories participating in the USGS National Sediment Laboratory Quality Assurance Program.

5. Review of the literature indicates that the TSS method originated as an analytical method for wastewater, presumably for samples collected after a settling step at a wastewater treatment facility. The results of this evaluation do not support use of the TSS method to produce reliable concentrations of solid-phase material in natural-water samples. The TSS method is being misapplied to samples from natural water.

Some SSC and TSS data may be comparable, particularly when the percentage or amount of sand-size material in the sample is less than about 25 percent. TSS values from analyses of samples collected following a settling step for coarser sediments, such as those obtained for compliance purposes at sewage treatment plants and water treatment facilities, may be reliable. However, because relatively few TSS data are associated with the percent sand-size and finer material from SSC samples, it is usually impossible to identify which if any TSS data may be biased. Some of the TSS data may reflect the mass of suspended solids in natural-water samples, but there are currently no absolute means to identify those data, nor a generally reliable procedure to correct biased TSS data.

The TSS method, which was originally designed for analyses of wastewater samples, is shown to be fundamentally unreliable for the analysis of natural-water samples. In contrast, the SSC method produces relatively reliable results for samples of natural water, regardless of the amount or percentage of sand-size material in the samples. SSC and TSS data collected from natural water are not comparable and should not be used interchangeably. The accuracy and comparability of suspended solid-phase concentrations of the Nation's natural waters would be greatly enhanced if all these data were produced by the SSC analytical method.

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THE STATE WATER RESOURCES CONTROL BOARD

WATER QUALITY ENFORCEMENT POLICY

draft revised Policy

October 19, 2000 Draft

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

TABLE OF CONTENTS

INTRODUCTION 1

I. FAIR, FIRM AND CONSISTENT REGULATION AND ENFORCEMENT 2

II. DISCOVERY OF VIOLATION 2

A. Self-Monitoring Reports 2

B. Compliance Inspections 2

C. Direct Facility Reporting 3

D. Complaints and Complaint Investigations 3

E. Case Record Maintenance and Review 3

III. DETERMINING SIGNIFICANT VIOLATIONS 4

A. NPDES Effluent and Receiving Water Limitation Violations 4

B. Chronic Violations 6

C. Toxicity Violations 6

D. Violations of Prohibitions 6

E. Spills (including other unauthorized discharges) 6

F. Failure to Submit Reports 7

G. Violations of Compliance Schedules 7

H. Failure to Implement a Pretreatment Program 7

I. Storm Water Program Violations 7

1. Industrial and Construction Discharges 7
2. Municipal Discharges 7
3. Failure to attain performance standards, failure to report and address violations and unauthorized discharges 8

J. Clean Water Act Section 401 Violations 8

K. Violation of Water Quality Objectives or Receiving Water Limitations 8

L. Discharge of Biosolids to Land 8

M. Other Discharges of Waste to Land (Non-Chapter 15 Facilities) 9

N. Failure to Pay Fees, Penalties or Liabilities 9

O. Falsifying Information 9

IV. ENFORCEMENT ACTIONS 9

A. Progressive Enforcement 9

B. Standard Language 9

C. Informal Enforcement Actions 10
1. Verbal Enforcement Actions and Staff Enforcement Letters 10
2. Notice of Violation (NOV) 10

D. Formal Enforcement Actions 11
1. Notices to Comply 11
2. Notices of Stormwater Noncompliance 12
3. Technical Reports and Investigations 12
4. Cleanup and Abatement Orders (CAOs) 12
5. Section 13300 Time Schedule Orders (TSOs) 13
6. Section 13308 Time Schedule Orders (13308 TSOs) 13
7. Cease And Desist Orders (CDOs) 13
8. Modification Or Rescission Of Waste Discharge Requirements 14
9. Administrative Civil Liability (ACL) 14
10. Referrals To Attorney General, District Attorney, United States (U.S.) Attorney or City Attorney 17
   a. Attorney General 17
   b. District Attorney, Circuit Prosecutor, or U.S. Attorney 18
   c. Civil versus Criminal Actions 19

E. Petitions of Enforcement Actions 19

V. SPECIFIC RECOMMENDED ENFORCEMENT 20

A. Knowingly Falsifying or Knowingly Withholding Information that is Required to be Submitted to State Regulatory Agencies 20

B. Failure to Submit Reports and Submittal of Inadequate Reports 21

C. Mandatory Minimum Penalties for NPDES Violations 22

D. Failure To Pay Annual Fees 23

E. Failure To Pay Administrative Civil Liabilities 23

F. Acute Toxicity and Public Health 24

VI. SPECIAL SITUATIONS 24
A. Violations at Federal Facilities 24
B. Integrated Enforcement 24
C. Oil Spills 25
D. Hazardous Waste Spills 25
E. Spills of Non-hazardous Materials 26
F. Solid Waste Facilities 26
VII. ACL PROCEDURES 27
A. Determination of the Total Liability 27
1. Step A. Initial Liability 28
2. Step B. Beneficial Use Liability 29
3. Step C. Economic Benefit 29
4. Step D. Base Amount 30
5. Step E. Conduct of the Discharger 31
6. Step F. Other Factors 32
7. Step G. Staff Costs 32
8. Step H. Ability to Pay 32
a. Businesses 32
b. Public Agencies 33
9. Step I. Statutory Maximum and Minimum Limits 33
B. Distribution of an ACLs Liability 33
1. Compliance Projects (CPs) 34
a. Examples of CPs 34
b. CP Qualification Criteria 34
c. ACL Actions Allowing CPs 34
2. Supplemental Environmental Projects (SEPs) 35
a. Examples of Supplemental Environmental Projects 35
b. SEP Qualification Criteria 35
c. ACL Actions Allowing SEPs 36
d. Public Process 36
VIII. DISCHARGER SELF-AUDITING 37
IX. ENFORCEMENT REPORTING BY RWQCBS 37
A. Summary Violation and Enforcement Reports 37
B. Spill Reporting 37

X. POLICY REVIEW AND REVISION 38

INTRODUCTION

The State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Boards (RWQCBs) (together "Boards") are the principal state agencies with primary responsibility for the coordination and control of water quality. In the Porter-Cologne Water Quality Control Act (Porter-Cologne), the Legislature declared that the "state must be prepared to exercise its full power and jurisdiction to protect the quality of the waters in the state from degradation . . ." (California Water Code section 13000). Porter-Cologne grants the Boards the authority to implement and enforce the water quality laws, regulations, policies and plans to protect the waters of the state. Timely and consistent enforcement of these laws is critical to the success of the water quality program and to ensure that the people of the State have clean water. It is the policy of the SWRCB that the Boards shall strive to be fair, firm and consistent in taking enforcement actions throughout the State, while recognizing the individual facts of each case. Toward that end, it is the intent of the SWRCB that the enforcement actions of the RWQCBs be in accordance with the provisions of this policy.

Enforcement serves many purposes. First and foremost, it assists in protecting the beneficial uses of waters of the State. Swift and sure enforcement orders can prevent threatened pollution from occurring and can promote prompt cleanup and correction of existing pollution problems. It ensures compliance with SWRCB and RWQCB regulations, plans, policies, and orders. Enforcement not only protects the public health and the environment, but also creates an "even playing field," ensuring that dischargers who comply with the law are not placed at a competitive disadvantage by those who do not. It also deters potential violators and, thus, further protects the environment. Other benefits result from a strong enforcement program. Monetary remedies, an essential component of an effective enforcement program, provide a funding source for needed cleanup projects, provide a measure of compensation for the often unquantifiable damage that pollution causes to the environment, and ensure that polluters do not gain a substantial economic advantage from violations of water quality laws.

Enforcement determinations may be complicated fact-specific decisions based ultimately on experience and professional judgment. The purpose of this Policy is to provide a framework within which such decisions may be better made. In deciding which course of action should be pursued, RWQCB staff should consult with their supervisors. In many cases, the final decision will be left to the RWQCB.

It is important to note that enforcement of the State's water quality requirements is not solely the purview of the Boards and their staff. Other agencies (e.g., the California Department of Fish and Game) have the ability to enforce certain water quality provisions in state law. State law also allows for members of the public to bring enforcement matters to the attention of the Boards and authorizes aggrieved persons to petition the SWRCB to review most actions or in-actions by the RWQCB. In addition, state and federal statutes provide for public participation in the issuance of most orders, policies and water quality control plans. Finally, the federal Clean Water Act authorizes citizens to bring suit against dischargers for certain types of Clean Water Act (CWA) violations.

I. FAIR, FIRM AND CONSISTENT REGULATION AND ENFORCEMENT

Fair, firm and consistent enforcement depends on a foundation of solid requirements in law, regulations, policies, and the adequacy of enforceable orders, including waste discharge requirements (WDRs), cleanup and abatement orders, National Pollutant Discharge Elimination System (NPDES) permits, and other orders. The extent to which such enforceable orders include well-defined requirements and apply similar requirements to similar situations affects the consistency of compliance and enforcement. Whenever the circumstances of a discharge (including the nature and volume of the discharge and the beneficial uses of the receiving water) are similar, the provisions of the enforceable orders should be comparable.

The SWRCB, with assistance and advice from the RWQCBs will compile and maintain examples of standard enforceable orders. RWQCBs' orders shall be consistent except as appropriate for the specific circumstances related to the discharge and to be consistent with applicable water quality control plans. Such modifications must be consistent with applicable state and federal law. RWQCB Water Quality Control Plans may include unique requirements that apply within a region and must be implemented even if not consistent with other RWQCBs.

The Boards shall have a consistent and valid means to determine compliance with enforceable orders. Compliance assurance activities include the review of self-monitoring reports, facility inspections and complaint response. RWQCBs shall regularly review all discharger self-monitoring reports and document all violations and the subsequent response in the Boards' enforcement data management system. Where enforcement resources are limited, actions should be targeted to the highest priority significant violations. Enforcement actions should be initiated as soon as possible after discovery of the violation. Violations that are similar in nature and have similar water quality impacts should receive similar enforcement.

II. DISCOVERY OF VIOLATION

Violation of WDRs, Water Quality Control Plan prohibitions, enforcement orders, and other provisions of law administered by the SWRCB or RWQCBs can be discovered through discharger self-monitoring reports (SMRs), compliance inspections, facility reporting, complaints, or file review.

A. Self-Monitoring Reports

The Boards ensure compliance with WDRs by requiring dischargers to implement a monitoring and reporting program under California Water Code sections 13267 and 13383, and to periodically submit SMRs. Reporting frequency for regulated dischargers depends on the nature and impact of the discharge. The regulations that implement the CWA also specify monitoring requirements. WDRs shall explicitly require the discharger to clearly identify violations of their WDRs in the SMR.

B. Compliance Inspections

Compliance inspections are conducted on-site by the RWQCB staff under the authority provided in California Water Code sections 13267 and 13383. Compliance inspections address compliance with WDRs, laboratory quality control and assurance, record keeping and reporting, time schedules, best management practices, pollution prevention plans, and any other pertinent requirements. The inspections are also used as a verification of the accuracy of the discharger's SMR.

C. Direct Facility Reporting

Dischargers with regulated facilities should generally be required through their WDRs to report to the RWQCB by phone, usually immediately or within 24 hours, followed by a written report and a discussion in the next SMR, when certain events occur, such as:

- Bypass of raw or partially treated sewage or other waste from a treatment unit or discharge of wastewater from a collection system.
- Treatment unit failure or loss of power that threatens to cause a bypass.
- Any other operational problems that threaten to cause significant violations of WDRs or impacts to receiving waters.
- Discharges of oil or petroleum in or on waters of the State or where it will be discharged in or on waters of the State.

D. Complaints and Complaint Investigations

Often information regarding an actual or potential violation or unauthorized discharge is obtained through telephone or written notification from a member of the public, another public agency or an employee working at a regulated facility. Complaints may also involve nuisance conditions, such as noxious odors that extend beyond a wastewater treatment plant boundary. The SWRCB Office of Operator Certification also investigates complaints of operator misconduct at wastewater treatment plants. During the course of an investigation additional violations that are indirectly related or unrelated to the original investigation may also be discovered.

E. Case Record Maintenance and Review

WDRs and enforcement orders (e.g., cleanup and abatement orders, cease and desist orders, time schedule orders and California Water Code section 13267 orders) frequently mandate completion of tasks, which the dischargers must confirm by submission of appropriate reports to the RWQCBs. Failure to submit the reports or to complete the required tasks may be the basis for additional enforcement. RWQCBs shall use data management systems to track tasks and reports required of dischargers.

Often the RWQCB first hears about spills or other violations from the California Department of Fish and Game, the California Department of Toxic Substance Control or other enforcement agencies. District Attorneys are another source on information. The RWQCBs can use this information to decide whether to initiate joint or separate enforcement actions.

III. DETERMINING SIGNIFICANT VIOLATIONS

Enforcement actions shall be targeted toward the highest priority water-quality violations (significant violations). The general criteria below have been developed to assist the RWQCBs in identifying significant violations in order to help establish priorities for enforcement efforts. Depending on the circumstances, violations that are not included on this list could nonetheless be considered "significant" as well.

The following subsections comprise a non-exclusive list of violations that are considered "significant," will be identified as significant violations in the enforcement database, and will be considered high priority for enforcement.

A. NPDES Effluent and Receiving Water Limitation Violations

For facilities with NPDES permits, the following effluent and receiving water limitation violations are significant violations:

- Any violation of an effluent limitation for a Group 1 pollutant (see Table III-1) by 40 percent or more. (If the effluent limitation is zero, any detection necessarily exceeds the effluent limitation by 40 percent or more.) In addition, where the effluent limitation is lower than the applicable detection limit, the discharge must also equal or exceed the applicable detection limit in order to be considered a significant violation. The applicable detection limit is the Minimum Level for discharges of priority pollutants subject to the SWRCB's "Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California," and the Practical Quantitation Limit for all other Group 1 pollutants.
- Any violation of an effluent limitation for a Group 2 pollutant (see Table III-2) by 20 percent or more. (If the effluent limitation is zero, any detection necessarily exceeds the effluent limitation by 20 percent or more.) In addition, where the effluent limitation is lower than the applicable detection limit, the discharge must also equal or exceed the applicable detection limit in order to be considered a significant violation. The applicable detection limit is the Minimum Level for discharges of priority pollutants subject to the SWRCB's "Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California," the Method Detection Limit for total residual chlorine, and the Practical Quantitation Limit for all other Group 2 pollutants.
- Any waste discharge that violates a flow limitation by ten percent or more.
- Any waste discharge that violates a receiving water temperature limitation by three degrees Celsius or more.
- Any waste discharge that violates an effluent or receiving water limitation for pH by one pH unit or more.
- Any waste discharge that violates an effluent or receiving water limitation for any other pollutant or monitored parameter that is not listed in either Table III-1 or Table III-2 by 40 percent or more.

Table III-1. Group 1 Pollutants. This list of pollutants is based on Appendix A to Section 123.45 of Title 40 of the Code of Federal Regulations. For the purpose of data entry into the Permit Compliance System (PCS), the United States Environmental Protection Agency (USEPA) has identified an exhaustive list of those pollutants which are included as Group 1 pollutants under the various classifications of "other." The list is available on the SWRCB's Internet site (www.swrcb.ca.gov). The entire list, including any future amendments by USEPA thereto, is hereby incorporated into this Table III-1.

Oxygen Demand
Biochemical Oxygen Demand
Chemical Oxygen Demand
Total Oxygen Demands
Total Organic Carbon
Other

Solids
Total Suspended Solids
Total Dissolved Solids
Other

Nutrients
Inorganic Phosphorous Compounds
Inorganic Nitrogen Compounds
Other

Detergents and Oils
Methylene Blue Active Substances
Nitrillotriacetic Acid
Oil and Grease
Other Detergents or Algicides

Minerals
Calcium
Chloride
Fluoride
Magnesium
Sodium
Potassium
Sulfur
Sulfate
Total Alkalinity
Total Hardness
Other Minerals

Metals
Aluminum
Cobalt
Iron
Vanadium

Table III-2. Group 2 Pollutants. This list of pollutants is based on Appendix A to Section 123.45 of Title 40 of the Code of Federal Regulations. For the purpose of data entry into the Permit Compliance System (PCS), USEPA has identified an exhaustive list of those pollutants which are included as Group 2 pollutants. The entire list is available on the SWRCB's internet site (www.swrcb.ca.gov). The entire list, including any future amendments by USEPA thereto, is hereby incorporated into this Table III-2.

Metals
All metals not specifically listed under Group 1.

Inorganics
Cyanide
Total Residual Chlorine

Organics
All organics not specifically listed under Group 1.

B. Chronic Violations

Chronic violations are significant violations. A facility or discharger is in chronic violation when it has four or more similar types of violations during any six-month period, or it has violated a monthly average effluent limitation for a specific pollutant in the same season for two consecutive years.

C. Toxicity Violations

Two or more violations of numeric or narrative toxicity requirements contained in WDRs, Water Quality Control Plan prohibitions or other provisions of law within any six-month period are significant violations.

D. Violations of Prohibitions

WDRs, Water Quality Control Plans, and enforcement orders often contain prohibitions (year-round or seasonal) against certain types of discharges of waste. Violations of such prohibitions are considered significant violations.

E. Spills (including other unauthorized discharges)

Significant violations include:

- sewage spills that reach surface waters;
- sewage spills to soil that are a public health threat and/or are greater than 5000 gallons; and

- spills of other materials that cause a public health threat or cause toxicity to fish and wildlife (e.g., hazardous materials and oil).

F. Failure to Submit Reports

Failure to submit reports required by WDRs, California Water Code section 13267 and 13383 orders, California Water Code section 13260, regulations or Water Quality Control Plans within 30 days from the due date, or submission of reports which are so deficient or incomplete as to impede the review of the status of compliance are significant violations. In addition, failure to comply with the notification requirements contained in California Water Code sections 13271 and 13272 is a significant violation.

G. Violations of Compliance Schedules

Violations of compliance schedule dates (e.g., schedule dates for starting construction, completing construction, or attaining final compliance) by 60 days or more from the compliance date specified in an enforcement order or WDRs are significant violations.

H. Failure to Implement a Pretreatment Program

Failure of a publicly-owned treatment works to substantially implement its approved pretreatment program as required in its WDRs, including failure to enforce industrial pretreatment requirements on industrial users and failure to meet pretreatment program compliance schedules within 60 days is a significant violation.

I. Storm Water Program Violations

1. Industrial and Construction Discharges

Certain construction and industrial activities require compliance with either the General NPDES Permit for Storm Water Discharges Associated with Construction Activity (Construction Storm Water Permit) or the General NPDES Permit for Discharges of Storm Water Associated with Industrial Activity Excluding Construction (Industrial Storm Water Permit). Failure to submit a Notice of Intent for coverage under the general permits or a notice of non-applicability, after specific notification to the discharger, is a significant violation. Failure to either develop a Storm Water Pollution Prevention Plan (SWPPP), to substantially implement a SWPPP, to conduct required monitoring, or to submit annual reports is a significant violation.

2. Municipal Discharges

In most urban areas, discharges of storm water to and from municipal separate storm sewer systems (MS4s) require compliance with a Municipal NPDES Storm Water Permit. Failure to either submit a report of waste discharge, to develop a storm water management plan, to substantially implement the storm water management plan, to conduct monitoring, or to submit an annual report is a significant violation.

3. Failure to attain performance standards, failure to report and address violations and unauthorized discharges

Most storm water permits require the discharger(s) to comply with general performance practices or standards (e.g., best management practices, best available technology economically achievable, best conventional technology, and maximum extent practicable). If storm water and/or authorized non-storm water discharges cause or substantially contribute to an exceedance of an applicable water quality standard, the discharger is usually required to take specific actions (e.g., modify its Storm Water Management Plan) to resolve such exceedances. For storm water and/or authorized non-storm water discharges that cause or substantially contribute to an exceedance of an applicable water quality standard, significant violations include the failure to comply with the procedures to address exceedances required by the permit. Discharges of non-storm water that are unauthorized by the permit are significant violations. The criteria for significant violations in section III(A) of this policy apply to NPDES storm water permits that contain effluent limitations.

J. Clean Water Act Section 401 Violations

Discharges into waters of the United States that require a federal permit or license also require certification from the SWRCB or RWQCB that the discharge will comply with the State's water quality standards. Failure to obtain certification prior to a discharge that causes or contributes to a condition of nuisance or pollution or violates water quality standards is a significant violation. Failure to substantially comply with conditions specified in the certification is a significant violation.

K. Violation of Water Quality Objectives or Receiving Water Limitations

Any discharge of waste resulting in, or likely to result in, a violation of a water quality objective or a receiving water limitation in groundwater or surface water, or in the creation of a condition of nuisance, is a significant violation unless specifically authorized by the SWRCB or RWQCB. For storm water discharges, RWQCBs may allow the iterative approach discussed in SWRCB Orders WQ 91-03, 91-04, 96-13, 98-01 and 99-05.

L. Discharge of Biosolids to Land

The following violations of the SWRCB General WDRs for discharge of biosolids to land are significant violations:

- Any discharge in violation of the setback requirements;
- Any discharge that exceeds 1.4 times the agronomic rate for nitrogen, where the site is not a land-reclamation site;
- Any discharge of tailwater in violation of the requirements;
- Any discharge that exceeds the Background Cumulative Adjusted Loading Rate in the requirements; and

- Any violation of the specific Class B Discharge Specifications.

M. Other Discharges of Waste to Land (Non-Chapter 15 Facilities)

The following violations of requirements in WDRs for facilities regulated by the Non-Chapter 15 Program are significant violations:
- The failure to maintain required freeboard in ponds;
- Any discharge that exceeds flow limits by 20 percent or more;
- Any discharge that exceeds the effluent limitation for biological oxygen demand or total dissolved solids by 100 percent or more; or
- Any discharge where the dissolved oxygen is less than 50 percent of the effluent limitation;

N. Failure to Pay Fees, Penalties or Liabilities

Failure to pay fees, penalties or liabilities within 30 days of the due date is a significant violation unless an alternate payment schedule has been accepted by the RWQCB Executive Officer or the SWRCB's Division of Administrative Services.

O. Falsifying Information

Falsification or intentional withholding of information required by an order of the SWRCB or a RWQCB is a significant violation.

IV. ENFORCEMENT ACTIONS

The Boards have a variety of enforcement tools to use in response to non-compliance by dischargers. This section describes the range of options and discusses procedures that are common to some or all of these options.

A. Progressive Enforcement

An enforcement action is any informal or formal action taken to address the failure to comply with applicable statutes, regulations, plans, policies, or orders of the Boards. For some violations, an informal response such as a phone call or staff enforcement letter is sufficient to inform the discharger that the violation has been noted by the RWQCB and to encourage a swift return to compliance. More formal enforcement is often an appropriate first response for more consequential violations. If the violation continues, the enforcement response should be escalated to increasingly more formal and severe actions until compliance is achieved. Progressive enforcement is not appropriate in all circumstances, for example, where there is an emergency situation needing immediate response for which a cleanup and abatement order is appropriate or where the discharger is a chronic violator.

B. Standard Language

In order to provide a consistent approach to enforcement throughout the state, enforcement orders should be standardized where appropriate. The SWRCB intends to maintain model enforcement orders containing standardized provisions for use by the RWQCBs. RWQCBs should use the models and modify terms and conditions as appropriate for the specific circumstances related to the discharge and to be consistent with RWQCB plans and policies.

C. Informal Enforcement Actions

An informal enforcement action is any enforcement action taken by SWRCB or RWQCB staff that is not defined in statute. An informal enforcement action can include any form of communication (verbal, written, or electronic) between SWRCB and/or RWQCB staff and a discharger about a violation or potential violation. These actions may, in some circumstances, be appealed to the RWQCB or the RWQCB Executive Officer but cannot be directly petitioned to the SWRCB.

The purpose of an informal enforcement action is to quickly bring a violation to the discharger's attention and to give the discharger an opportunity to return to compliance as soon as possible. The RWQCB may take formal enforcement action in place of, or in addition to, informal enforcement actions. Continued noncompliance should trigger formal enforcement action.

1. Verbal Enforcement Actions and Staff Enforcement Letters

For many violations, the first step is a verbal enforcement action. Staff should contact the discharger by phone or in person and inform the discharger of the specific violations, discuss how and why the violations occurred, and discuss how and when the discharger will correct the violation and achieve compliance. Staff shall document the conversation in the facility case file and in the enforcement database.

A staff enforcement letter is often appropriate as follow-up, or in lieu of, a verbal enforcement action. Staff enforcement letters are signed by staff or by the appropriate senior staff. The letter should inform the discharger of the specific violations, and, if known to staff, discuss how and why the violations occurred and how and when the discharger will correct the violation and achieve compliance.

Verbal enforcement actions and staff enforcement letters should not include language that excuses the violation or that modifies a compliance date in WDRs or other orders issued by the State or RWQCB.

2. Notice of Violation (NOV)

The NOV letter is the highest level of informal enforcement action. An NOV letter shall be signed by the RWQCB Executive Officer or designee and shall be addressed and mailed to the discharger(s). In cases where staff normally work with the discharger's consultant, the consultant should also receive a copy of the letter. The NOV letter shall include the following information: description of specific violations, summary of appropriate enforcement options (including the potential daily or per gallon maximum Administrative Civil Liability (ACL) available), and a request for a written response by a specified date. The summary of applicable enforcement options shall include appropriate citations to the California Water Code and note that the RWQCB reserves the right to take any other enforcement action authorized by law.

D. Formal Enforcement Actions

Formal enforcement actions are statutorily recognized actions to address a violation or threatened violation of water quality laws, regulations, policy or orders. Formal enforcement orders generally shall contain findings that address the statutory requirements of the specific statutory provision being utilized.

1. Notices to Comply

Notices to Comply are issued pursuant to California Water Code section 13399 et seq., which requires the use of Notices to Comply as the sole enforcement option in most situations involving "Minor" violations.

The violations listed below are generally considered to be minor in nature:

- Inadvertent omissions or deficiencies in recordkeeping that do not prevent an overall compliance determination.
- Records (including WDRs) not physically available at the time of the inspection provided the records do exist and can be produced in a timely manner.
- Inadvertent violations of insignificant administrative provisions that do not involve a discharge of waste or a threat thereof.
- Violations that result in an insignificant discharge of waste or a threat thereof; provided, however, there is no significant threat to human health, safety, welfare or the environment and provided further that such violations do not violate any other order or prohibition issued by the SWRCB or RWQCBs. Significant threat means the threat of or an actual change in water quality that could result in a violation of water quality objectives or cause or contribute to a condition of pollution or nuisance.

A violation is not considered minor in nature if it is a significant violation as described in Section III of this policy or includes any of the following:

- It involves any knowing, willful, or intentional violation of Division 7 (commencing with Section 13000) of the California Water Code.
- It involves any violation of Division 7 of the California Water Code that enables the violator to benefit economically from noncompliance, either by realizing reduced costs or by gaining a competitive advantage.
- It cannot be corrected within 30 days.

2. Notices of Stormwater Noncompliance

The Stormwater Enforcement Act of 1998 (California Water Code section 13399.25 et seq.) requires that each RWQCB notify storm water dischargers who have failed to file a notice of intent to obtain coverage, a notice of non-applicability, a construction certification, or annual reports. If, after two notifications, the discharger fails to file the applicable document a mandatory civil liability shall be assessed against the discharger.

3. Technical Reports and Investigations

California Water Code sections 13267(b) and 13383 allow RWQCBs to conduct investigations and to require technical or monitoring reports in accordance with the conditions in the section. Failure to comply with orders made pursuant to Section 13267(b) may result in administrative civil liability pursuant to Section 13268. Failure to comply with orders made pursuant to Section 13383 may result in administrative civil liability pursuant to Section 13385. Section 13267(b) and 13383 orders are formal orders that are enforceable when signed by the Executive Officer of the RWQCB.

It is important to note that California Water Code sections 13267 and 13383 are not strictly enforcement statutes. They are the statutes that RWQCBs should routinely cite as authority whenever asking for technical or monitoring reports. It should also be cited in all WDRs as authority for the monitoring and reporting program.

4. Cleanup and Abatement Orders (CAOs)

Cleanup and Abatement Orders (CAOs) are adopted pursuant to California Water Code section 13304. CAOs are often issued to dischargers that are not being regulated by WDRs. CAOs are issued by the RWQCB, or by the Executive Officer under delegation from the RWQCB pursuant to California Water Code section 13223. RWQCBs should keep an accurate record of staff oversight costs for CAOs, because dischargers are liable for such costs. If staff costs are not recovered voluntarily or through civil court actions, the RWQCB may request that a lien be placed on the affected property.

RWQCBs shall comply with SWRCB Resolution No. 92-49 in issuing CAOs. CAOs should require discharger(s) to clean up the pollution to the most stringent levels that are economically and technically feasible. At a minimum, cleanup levels must be sufficiently stringent to fully support beneficial uses, unless the RWQCB allows a containment zone. In the interim, and if full cleanup cannot be achieved, the CAO should require the discharger(s) to abate the effects of the discharge. Abatement activities may include the provision of alternate water supplies. CAOs should name all dischargers for which there is substantial evidence of responsibility.

CAOs shall contain language describing likely enforcement options available for non-compliance and should specify that the RWQCB reserves its right to take any enforcement action authorized by law. Such language shall include appropriate California Water Code citations. Violations of CAOs should trigger further enforcement in the form of an ACL, a Time Schedule Order (TSO) under California Water Code section 13308, or referral to the Attorney General for injunctive relief or monetary remedies.

5. Section 13300 Time Schedule Orders (TSOs)

Pursuant to California Water Code section 13300, the RWQCBs or the Executive Officers can require the discharger to submit a time schedule which sets forth the actions that the discharger will take to address actual or threatened discharges of waste in violation of requirements.

6. Section 13308 Time Schedule Orders (13308 TSOs)

California Water Code section 13308 authorizes the RWQCB to issue a Section 13308 Time Schedule Order (13308 TSO) which prescribes a daily civil penalty if compliance is not achieved in accordance with the time schedule. The RWQCB may issue a 13308 TSO if there is a threatened or continuing violation of a cleanup and abatement order, cease and desist order, or any order issued under California Water Code sections 13267 or 13383. The daily penalty must be set based on an amount reasonably necessary to achieve compliance and may not contain any amount intended to punish or redress previous violations. Therefore, the 13308 TSO should contain findings explaining how the daily penalty amount will induce compliance without imposing punishment. For example, it could include a calculation of how much money the discharger is saving each day by delaying compliance. The 13308 TSO provides the RWQCBs with their primary mechanism for motivating compliance, and if necessary, assessing monetary penalties against federal facilities.

If the discharger fails to comply with the 13308 time schedule, the daily penalty is imposed when the RWQCB Executive Officer issues an ACL Complaint. The amount proposed in the ACL complaint should be equal to the daily penalty multiplied by the days of violation. If the amount of proposed liability in the ACL Complaint is less than the amount specified in the 13308 Order, the ACL Complaint shall include specific findings pursuant to California Water Code section 13327. The penalty may not exceed $10,000 for each day in which a violation of the 13308 TSO occurs.

7. Cease And Desist Orders (CDOs)

Cease and Desist Orders (CDOs) are adopted pursuant to California Water Code sections 13301-13303. CDOs may be issued to dischargers violating or threatening to violate WDRs or prohibitions prescribed by the RWQCB or the SWRCB. CDOs are often issued to dischargers with chronic non-compliance problems. These problems are rarely amenable to a short-term solution; often, compliance involves extensive capital improvements or operational changes. The CDO will usually contain a compliance schedule, including interim deadlines (if appropriate), interim effluent limits (if appropriate), and a final compliance date. CDOs may also include restrictions on additional service connections to community sewer systems.

CDOs shall contain language describing likely enforcement options available for non-compliance and specify that the RWQCB reserves its right to take any further enforcement action authorized by law. Such language shall include appropriate California Water Code citations. Violations of CDOs should trigger further enforcement in the form of an ACL, 13308 Order or referral to the Attorney General for injunctive relief or monetary remedies.

8. Modification Or Rescission Of Waste Discharge Requirements

In accordance with the provisions of the California Water Code, the RWQCB may modify or rescind WDRs in response to violations. Examples of cases where rescission of WDRs may be appropriate include: failure to pay fees, penalties or liabilities; discharges that impact beneficial uses of the waters of the state; and violation of the SWRCB General WDRs for discharge of biosolids due to exceedance of the Background Cumulative Adjusted Loading Rate. Rescission of WDRs generally is not an appropriate enforcement response where the discharger is unable to prevent the discharge, as in the case of a publicly owned wastewater treatment plant.

9. Administrative Civil Liability (ACL)

ACL means monetary assessments imposed by a RWQCB. The California Water Code and the Health and Safety Code authorize ACLs in several circumstances which are summarized in Table IV-1. Staff working on ACLs should consult the appropriate section of the California Water Code to review the entire text.

Table IV-1. Summary of California Water Code and Health and Safety Code Authority for Imposing Administrative Civil Liability.

STATUTE	COVERAGE
§ 13261 (California Water Code)	Up to $1,000 per day for failure to furnish reports of waste discharge or failure to pay annual program fees. ($5,000 per day for non-NPDES discharges if hazardous waste is involved and there is a willful violation.)
§ 13265 (California Water Code)	Up to $1,000 per day for discharging without a permit. ($5,000 per day for non-NPDES discharges if hazardous waste is involved and violation is due to negligence.)
§ 13268 (California Water Code)	Up to $1,000 per day for failing or refusing to furnish technical or monitoring reports or falsifying information therein. (Up to $5,000 per day for non-NPDES discharges if hazardous waste is involved and there is a knowing violation.)

§ 13271 (California Water Code)	Up to $20,000 or imprisonment for not more than 1 year or both for failing to notify the Office of Emergency Services (OES) of a discharge of hazardous substances or more than 1000 gallons of sewage.
§ 13272 (California Water Code)(Limitation: Does not apply to spills of oil into marine waters as defined in Government Code §8670.3(f).)	Imprisonment for not more than 1 year or a fine of not less than $500 and not more than $5000 per day for each day of failure to notify OES of a discharge of any oil or product in or on the waters of the state.
§ 13308 (California Water Code)	Up to $10,000 per day for violations of time schedules. Amount to be prescribed when time schedule is established.
§ 13350 (California Water Code)(Limitations: Must show intentional or negligent violation of cease and desist order or cleanup and abatement order; must also show that pollution or nuisance occurred if any other order, including waste discharge requirements, is violated. Strict liability with defenses if hazardous substances are involved.)	• Up to $10 per gallon of waste discharged (if no cleanup and abatement order has been issued). • Between $500 and $5,000 per day if a cleanup and abatement order has been issued. • If there is no discharge, but an order of the RWQCB is violated: Between $100 and $1,000 for each day of violation.
§ 13385 (California Water Code) (Limited in scope of NPDES permit program, e.g., point source discharges to surface waters. Strict liability applies.)	For NPDES permit program violations: Up to $10,000 per day of violation plus an additional liability of $10 per gallon for each gallon over 1,000 gallons where there is a discharge that is not cleaned up.
§ 13385 (California Water Code)	• 13385 (h) (1) … Mandatory minimum penalties of three thousand dollars ($3,000) shall be assessed for the first serious violation and each additional serious violation in any period of six consecutive months, except that the state board or regional board may elect to require the discharger to spend an amount equal to the penalty for the first serious violation on a supplemental environmental project or to develop a pollution prevention plan. • 13385 (i) Mandatory minimum penalties of three thousand dollars ($3,000) shall be assessed for each violation whenever the person does any of the following four or more times in any period of six consecutive months, except that the requirement to assess the mandatory minimum penalty shall not be

	applicable to the first three violations: (1) Exceeds a waste discharge requirement effluent limitation. (2) Fails to file a report pursuant to Section 13260. (3) Files an incomplete report pursuant to Section 13260. (4) Exceeds a toxicity discharge limitation contained in the applicable waste discharge requirements where the waste discharge requirements do not contain pollutant-specific effluent limitations for toxic pollutants.
§ 13399.33 (California Water Code) (Penalties may be reduced for specified reasons.)	• Not less than $5,000 per year or fraction thereof for failure to submit required notice of intent for coverage under stormwater permit. • Not less than $1,000 per year or fraction thereof for failure to submit notices on non-applicability, annual reports or construction certification as required by stormwater program.
§ 13627.3 (California Water Code)	Fines of up to $100 per day for persons operating wastewater treatment plants without the appropriate grade of license. Up to $1,000 per day for failure to provide reports on wastewater treatment plant operators.
§ 25284.4 (H&S Code) (Special provision covering underground storage tanks.)	For violation of tank integrity testing provisions, up to $500 per day.

California Water Code sections 13323-13327 describe the process to be used to assess ACLs. The California Water Code authorizes RWQCB Executive Officers to issue an ACL Complaint. Section VII of this policy provides specific instructions for staff to use when preparing ACL documents. The ACL Complaint describes the violation, includes a calculation of maximum potential liability, proposes a specific monetary assessment, and sets a hearing date (within 60 days after the Complaint is served). ACLs issued under section 13385 for violations of the CWA require that the hearing must be held at least 30 days after the issuance of the complaint in order to comply with public notice requirements.

ACL Complaint

Upon receipt of an ACL Complaint the discharger(s) may either waive their rights to a hearing and pay the liability; negotiate a settlement (usually memorialized in the form of an amended complaint) and comply with the terms of that settlement; or appear at the RWQCB hearing to dispute the Complaint. In the latter case, the RWQCB will consider whether to affirm, modify or reject the liability proposed by adopting an ACL order. If the RWQCB adopts an ACL Order, it may be for an amount that is greater or less than the amount proposed in the complaint but may not exceed the maximum statutory liability.

Suspended Liability

The RWQCB may, by various means, allow a portion of the liability to be satisfied through the successful completion of a Supplemental Environmental Project (SEP) and/or a Compliance Project (CP). The remaining portion of the liability shall be paid to the State Cleanup and Abatement Account. The specific procedures for suspending liability for SEPs and CPs are discussed in greater detail in Section VIII of this policy.

Staff Costs

The portion of the ACL amount that is intended to recover staff costs should always be paid to the State Cleanup and Abatement Account. Staff costs are discussed in greater detail in Section VII of this policy.

ACL Order

ACL Orders are final upon adoption and cannot be reconsidered by the RWQCB. Thus, the RWQCB may want to include a clause in the time schedule for completing SEPs or CPs that reserves its jurisdiction to modify the time schedule if it, or its Executive Officer, determines that the delay was beyond the reasonable control of the discharger. If the RWQCB fails to reserve jurisdiction for this purpose, the time schedule in the ACL Order can only be modified by the SWRCB pursuant to California Water Code section 13320. Another option that allows some flexibility in the time schedule for a CP is for the Board to adopt a CAO or a CDO at the same time it adopts the ACL Order. The time schedule in the CAO or CDO, subject to any future amendments to the CAO or CDO, would then be incorporated into the ACL Order by reference. All cash payments to the SWRCB or RWQCBs, including previously suspended liabilities assessed for failure to comply with CPs or SEPs, shall be paid to the State Cleanup and Abatement Account.

10. Referrals To Attorney General, District Attorney, United States (U.S.) Attorney or City Attorney

The RWQCB can refer violations to the state Attorney General or U.S. Attorney or request the appropriate county District Attorney or City Attorney to seek criminal relief. A superior court judge may be requested to impose civil or criminal penalties. In some cases (e.g., when the District Attorney or Attorney General is unable to accept a case), the RWQCB may find it appropriate to request the U.S. Attorney's Office to review potential violations of federal environmental statutes, including the CWA, the Endangered Species Act, the Migratory Bird Treaty Act, or the Resource Conservation and Recovery Act.

a. Attorney General

The Attorney General can seek judicial civil liabilities for a variety of California Water Code violations, essentially the same ones for which the RWQCB can impose ACL. Maximum per-day or per-gallon civil monetary remedies are two to ten times higher when imposed by the court instead of the RWQCB. The Attorney General can also seek injunctive relief in the form of a restraining order, preliminary injunction, or permanent injunction pursuant to California Water Code sections 13262, 13264, 13304, 13331, 13340 and 13386. Injunctive relief may be appropriate in emergency situations, or where a discharger has ignored enforcement orders or does not have the ability to pay a large ACL.

For civil assessments, referrals to the Attorney General should be reserved for cases where the violation merits a significant enforcement response but where an ACL would be inappropriate or ineffective. For example, when a major oil spill occurs, several state agencies can seek civil monetary remedies under different state laws; a single civil action by the Attorney General may be more efficient than numerous individual agency actions. A violation (or series of violations) with major public health or water quality impacts should be considered for referral in order to maximize the monetary assessment because of its effect as a deterrent. Referral for recovery of natural resources damages under common law theories, such as nuisance, may also be appropriate.

b. District Attorney, Circuit Prosecutor, or U.S. Attorney

District Attorneys may seek civil or criminal penalties under their own authority for some of the same violations the RWQCB pursues. While the California Water Code requires a formal RWQCB referral to the Attorney General, the RWQCB's Executive Officer is not precluded from bringing appropriate matters to the attention of a District Attorney. A major area where District Attorney involvement should be considered is for unauthorized releases of hazardous substances. In most of these cases, the RWQCB is not the lead agency, and the referral action is intended to support the local agency or another state agency that is taking the lead (e.g., county health department, city fire department, California Department of Fish and Game or the California Department of Toxic Substances Control). In many cases, RWQCB staff lacks the time to prepare an enforcement action, and a District Attorney referral is another option to seeing the matter pursued. Many District Attorney offices have created task forces specifically staffed and equipped to investigate environmental crimes including water pollution. These task forces may ask for RWQCB support which should be given within available resources. District Attorneys also have the resources to carry out investigations that may be beyond the expertise of RWQCB staff. For example, a District Attorney's investigator is skilled at interviewing witnesses and collecting evidence. Such assistance can help a RWQCB to determine if enforcement action is required and help with developing the evidence needed to prove the basis for enforcement.

The California District Attorneys Association has established the Environmental Circuit Prosecutor Project to provide experienced environmental attorneys to rural California counties. Circuit Prosecutors are deputized as needed in counties that lack the resources to have a prosecutor experienced in environmental law as a full time employee.

In addition to the criminal sanctions and civil fines, the District Attorney or Circuit Prosecutor often pursues injunctive actions to prevent unfair business advantage. The law provides that one business may not gain unfair advantage over its competitors by using prohibited tactics. A business that fails to comply with its WDRs or an enforcement order competes unfairly with other businesses that obey the law.

In cases where there is a serious violation of the CWA and additional investigatory resources are needed, the U.S. Attorney may be contacted.

c. Civil versus Criminal Actions

Enforcement actions taken by the RWQCB are administrative or civil actions. In cases where there is reason to believe that specific individuals or entities have engaged in criminal conduct, the RWQCB or Executive Officer may request that criminal actions be pursued by the District Attorney, Attorney General, or U.S. Attorney. Under criminal law, individual persons, as well as responsible parties in public agencies and business entities, may be subject to fines or imprisonment.

While criminal statutes differ, many require some type of intent or knowing behavior on the part of the violator. This intent may be described as knowing, reckless, or willful. In addition to the required intent, criminal offenses usually consist of a number of elements, each one of which must be proven. Determining whether the required degree of intent and each of the elements exists often involves a complex analysis. If a potential environmental criminal matter comes to the attention of staff, consultation with RWQCB management and counsel should take place first before making any contact with other enforcement authorities.

When evaluating whether a case should be referred for criminal investigation, particular attention should be given to the degree of intent and the gravity of the violation. A good rule of thumb is that if the conduct appears to be intentional or reckless and constitutes a serious threat to human health or the environment, careful consideration should be given to pursuing the case criminally.

E. Petitions of Enforcement Actions

Persons affected by most formal enforcement actions or failures to act by a RWQCB may file petitions with the SWRCB for review of such actions or failures to act. The petition must be received by the SWRCB within 30 days of the RWQCB action. A petition on the RWQCB's failure to act must be filed within 30 days of the date the RWQCB refuses to act or within 60 days after a request has been made to the RWQCB to act. Actions taken by the Executive Officer of the RWQCB pursuant to authority delegated by the RWQCB (e.g., cleanup and abatement orders) are considered actions by the Board and are also subject to the 30-day time limit. In addition, significant enforcement actions by a RWQCB Executive Officer may be reviewed by the RWQCB at the request of the

Discharger. Lastly, the SWRCB may, at any time and on its own motion, review most actions or failures to act by a RWQCB.

V. SPECIFIC RECOMMENDED ENFORCEMENT

It is the intent of the SWRCB that the following specific instances of non-compliance receive consistent enforcement responses from all nine RWQCBs. Decisions by the SWRCB and RWQCB to deviate from these specific recommendations should be based on extenuating circumstances that are documented in the discharger/facility record (e.g., file, databases, other records).

A. Knowingly Falsifying or Knowingly Withholding Information that is Required to be Submitted to State Regulatory Agencies

The foundation of the State's regulatory program relies on dischargers to accurately, and honestly, report information required by the Boards. This required information includes, but is not limited to: influent and effluent quality and flow data; surface and ground water data; spills of untreated or partially treated wastewater; and technical reports. Knowingly falsifying or knowingly withholding such information that would indicate violations of requirements contained in board orders, plans and policies erodes the State's regulatory program and places the health of the public and the environment at risk. The Boards shall respond to any instance of falsification or withholding of required information in accordance with this policy.

The discharger is responsible for compliance with orders and reporting of required information, including violations, to the SWRCB or RWQCB. The discharger is also responsible for ensuring that any employees, agents, or contractors acting on its behalf report truthful, accurate and timely required information. WDRs shall require training, specific signature authorization, audits, and procedures to ensure that dischargers, including their designees and employees are providing truthful, accurate, and timely reporting of required information.

The Boards shall consistently enforce the statutes pertaining to falsification or withholding of required information as follows:

- Initiate investigation of all instances of suspected falsification or withholding of water quality data within thirty days of becoming aware of the allegations. If the results of preliminary investigation suggest a possibility of criminal wrongdoing by the discharger, the SWRCB and RWQCB staff shall consult with management and counsel and inform the appropriate criminal investigative agency. The State and the RWQCBs may still pursue administrative actions against the discharger, however, prior to initiating any administrative or civil procedure, the criminal investigators and/or prosecutors must be consulted to insure that the administrative and civil process does not interfere with, or jeopardize, the criminal investigation.

R0026506

- Protect the confidentiality of all staff investigations of potential instances of knowingly falsifying or withholding required information. The RWQCBs shall protect the complainant's personal information such as name, address, phone numbers and employment data by providing a secure location for files about matters related to ongoing criminal investigations or licensing (e.g., treatment plant operator certification). The information in these files shall not be released to the public except as the law may require.

- Refer all cases where the investigation supports the allegation of falsification or intentional withholding of water quality data to the District Attorney, Circuit Prosecutor, Attorney General or the U.S. Attorney for criminal investigation.

- The SWRCB shall promptly consider, pursuant to California Water Code section 13627, suspension or revocation of the Operator Certificate of any operator who knowingly falsifies required information submitted to the SWRCB or RWQCB, withholds required information from the SWRCB or RWQCB, submits false or misleading information on an application for operator certification, or through threats, coercion or intimidation forces others to falsify or withhold required information from the SWRCB or RWQCB. Prior to initiating an investigation of potential operator misconduct involving falsification or withholding of information, the SWRCB's Office of Operator Certification shall insure that its investigation does not interfere with or jeopardize any potential criminal procedure.

- The RWQCB should assess civil liability against any facility where there is sufficient evidence of falsification or intentional or negligent withholding of required information.

- Where appropriate, the RWQCB shall, at a public meeting consider rescinding existing waste discharge requirements where the investigation supports the allegation of falsification or withholding of required information.

- The RWQCB should implement an intensive inspection schedule (e.g., semi-monthly inspections for a period of six months) for any facility where the investigation supports the allegation of falsification or withholding of water quality data. Inspections should involve thorough review of facility water quality records, procedures and processes, and sampling of effluent at regular intervals. Requesting the assistance of the District Attorney, Attorney General, or U.S. Attorney should be considered in complex cases.

B. Failure to Submit Reports and Submittal of Inadequate Reports

As stated above, the foundation of the State's water quality regulatory program relies on dischargers to report information specified in the WDR or in an order. If the discharger fails to submit a report, or submits a report that is inadequate (i.e., so deficient or incomplete as to impede the review of the status of compliance) the RWQCB should notify the discharger of the violation. At a minimum, the RWQCB should take an informal enforcement action if the discharger does not correct the violation within 30 days of the notification, and should issue an ACL if the discharger does not correct the violation within 60 days of the notification.

C. Mandatory Minimum Penalties for NPDES Violations

Mandatory penalty provisions are required by California Water Code section 13385(h) and (i) for specified violations of NPDES permits. A mandatory minimum penalty of $3,000 shall be assessed by the RWQCB. As an alternative to assessing $3,000 for the first serious violation in a six-month period, the RWQCB may require the discharger to spend an equal amount on a supplemental environmental project (SEP) or a pollution prevention plan (PPP). A serious violation is any waste discharge that exceeds the effluent limitation for a Group II pollutant by 20 percent or more, or a Group I pollutant by 40 percent or more. (See Tables III-1 and III-2)

If the RWQCB allowed the discharger to prepare a PPP pursuant to California Water Code section 13263.3 or an SEP in lieu of paying $3,000 for the first violation, the RWQCB must wait until the discharger has not had any serious violations for six months before it can allow the discharger to prepare an SEP or PPP in lieu of the mandatory penalty for additional serious violations.

The RWQCB shall assess mandatory minimum penalties of $3,000 per violation, not counting the first three violations, if the discharger does any of the following four or more times in any six-month period:

- exceeds WDR effluent limitations;
- fails to file a report of waste discharge or files an incomplete report of waste discharge pursuant to California Water Code section 13260; or
- exceeds a toxicity discharge limitation where the WDRs do not contain pollutant-specific effluent limitations for toxic pollutants.

The six-month time period shall be calculated as a "rolling" six months.

The intent of these portions of the California Water Code is to assist in bringing the State's waters into compliance with WDRs. RWQCBs should issue mandatory minimum penalties within seven months of the first qualifying violation, or sooner if the total mandatory penalty amount is $30,000 or more. This will encourage the discharger to correct the violation in a timely manner.

A single operational upset which leads to simultaneous violations of one or more pollutant parameters shall be treated as a single violation. EPA defines "single operational upset as "an exceptional incident which causes simultaneous, unintentional, unknowing (not the result of a knowing act or omission), temporary noncompliance with more than one CWA effluent discharge pollutant parameter. Single operational upset does not include... noncompliance to the extent caused by improperly designed or inadequate treatment facilities." "Issuance of Guidance Interpreting Single Operational Upset" Memorandum from Robert G Hess, Assistant Enforcement Counsel, September 27, 1989. The EPA Guidance further defines an "exceptional" incident as a "non-routine malfunctioning of an otherwise generally compliant facility." Single operational upsets include such things as upset caused by a sudden violent storm, a bursting tank, or other exceptional event and may result in multiple violations of the same effluent limitation. The discharger has the burden of demonstrating a single operational upset occurred. The RWQCB shall apply the above EPA Guidance in determining if a single operational upset occurred. It is not a defense to liability, but may affect the number of violations.

D. Failure To Pay Annual Fees

California Water Code section 13260 requires that each person prescribed WDRs shall pay an annual fee, except confined animal feeding or holding operations, which have a one-time $2,000 fee. Failure to pay the fee when requested is a misdemeanor and may be subject to an ACL imposed by the RWQCB of up to $1,000 per day pursuant to California Water Code section 13261. If the annual fee is not paid within 30 days of the invoice, the SWRCB staff shall issue a Notice of Violation for the annual fee which informs the recipient of the amount due and states that non-payment of the fee could result in one or more of the following:

- an ACL imposed by the RWQCB not to exceed $1,000 per day;
- a civil liability imposed by the superior court not to exceed $5,000 per day;
- recission of existing WDRs; or
- prosecution as a misdemeanor.

If the fee is not paid within 30 days of the Notice of Violation an ACL Complaint should be issued by the RWQCB Executive Officer. The amount of an ACL for nonpayment of fees should reflect an escalation of liability if there is a past history of failure to pay fees. In addition to the ACL, the discharger remains responsible for payment of the annual fees.

E. Failure To Pay Administrative Civil Liabilities

The SWRCB shall pursue collection of unpaid administrative civil liabilities. The California Water Code states that ACLs shall be paid within 30 days of the RWQCB's adoption of an ACL Order unless the recipient files a petition for review under California Water Code section 13320. When a petition is filed, payment is extended during the SWRCB review of the petition and shall be paid within 30 days of the SWRCB's decision on the petition. If the recipient fails to seek judicial review within 30 days of the SWRCB action, the SWRCB shall file for a judgment to collect the ACL pursuant to California Water Code section 13328. Application shall be made to the appropriate court in the county in which the liability was imposed, generally within 60 days of the failure to pay.

As an alternative to Section 13328, the SWRCB or RWQCB may pursue judicial collection for failure to pay an ACL imposed for CWA violations pursuant to California Water Code section 13385. After the time for judicial review has expired, the California Water Code provides that the Attorney General upon request shall petition the appropriate court to collect the liability. The person failing to pay the liability on a timely basis shall be required to pay interest, attorney's fees, cost for collection proceedings and a quarterly nonpayment fee of 20 percent for the liability and the nonpayment fees unpaid at the beginning of each quarter.

F. Acute Toxicity and Public Health

Where any violation can be shown to be the result of failure of a discharger to exercise normal care in handling, treating, or discharging waste, and that failure has resulted in acute toxicity to fish or wildlife and/or a public health threat, civil liability should be assessed.

VI. SPECIAL SITUATIONS

A. Violations at Federal Facilities

The CWA and the Resource Conservation and Recovery Act contain limited waivers of sovereign immunity. Due to sovereign immunity, the State cannot assess penalties or liabilities against federal agencies for past violations (e.g., no ACLs) under most circumstances. One significant exception is provided by the Federal Facilities Compliance Act of 1992 (42 USCA 6901 et seq), which allows the States to penalize federal agencies, under specified circumstances, for violations of state hazardous waste management requirements. In addition, under California Water Code section 13308, a RWQCB may seek an ACL, up to a maximum of $10,000 per day of violation, against federal facilities for any violation of a time schedule order. The time schedule order issued pursuant to Section 13308 prescribes a daily civil penalty which is based upon the amount necessary to achieve future compliance with an existing enforcement order. The RWQCB should take the action administratively, but if the federal government declines to pay, the RWQCB must refer the matter to the Attorney General's Office to file an action in state or federal court. Congress must waive sovereign immunity for the State to assess penalties or liability against the federal government.

B. Integrated Enforcement

SWRCB and RWQCB staff should cooperate with other environmental regulatory agencies, where appropriate, to ensure that enforcement actions are coordinated. The aggregate enforcement authorities of the Boards and Departments of the California Environmental Protection Agency (Cal/EPA) and the Resources Agency should be coordinated to eliminate inconsistent and inappropriately duplicative efforts. The following steps should be taken by RWQCB staff to assist in integrated enforcement efforts:

- participate in multi-agency enforcement coordination;
- share enforcement information; participate in cross-training efforts; and
- participate with other agencies in enforcement efforts focused on specific individuals or categories of discharges.

C. Oil Spills

Responses to oil spills to marine or estuarine waters should be coordinated through the Department of Fish and Game's Office of Oil Spill Prevention and Response (OSPR). OSPR staff may pursue enforcement action administratively or through referral to the local District Attorney. Staff should assist in an investigation by providing documentation, sampling, etc. If the discharger has not prepared a spill prevention plan or the plan is not acceptable to the RWQCB, the RWQCB should request a technical report under California Water Code sections 13267 or 13383. Major oil spills, those in excess of 10,000 gallons, usually involve a number of governmental jurisdictions. Such spills should be brought to the RWQCB for consideration of referral to the Attorney General for recovery of civil liability and other remedies.

Oil spills to inland (fresh) waters are not within the jurisdiction of OSPR. If formal enforcement actions are taken, they are usually enforced by either the county District Attorney under either the Fish and Game Code or Health and Safety Code, or by the RWQCB under the California Water Code. In general, if the District Attorney is interested in pursuing the case, the RWQCB should consult with the District Attorney before pursuing its own enforcement action to avoid any potential double jeopardy issues. However, staff should always request that any settlement by the District Attorney include recovery of staff costs and require any actions that appear necessary to prevent recurrence of a spill and/or to mitigate damage to the environment. If a District Attorney is the enforcement lead, RWQCB staff should generally focus their efforts on cleanup and prevention of future spills.

D. Hazardous Waste Spills

Hazardous wastes are those meeting the criteria specified in Title 22, Division 4.5, Chapter 11, California Code of Regulations. RWQCB staff shall coordinate enforcement actions involving hazardous waste spills with the California Department of Toxic Substances Control and/or any local or county hazardous waste program. Spills constitute unlawful disposal of hazardous waste pursuant to the Health and Safety Code. RWQCB staff should consider referring spills in all but the smallest amounts to the appropriate District Attorney. In addition, the RWQCB should consider assessing an ACL unless the spill was very small or limited in impact. Due to the nature of the materials discharged, the RWQCB should consider assessing an ACL in an amount at or near the legal maximum. If the California Department of Toxic Substances Control is seeking penalties or damages through a referral to the Attorney General, the RWQCB may consider joining that action in lieu of assessing an ACL.
Large spills of hazardous waste or hazardous substances, 10,000 gallons or more, should be treated like large oil spills, and should be considered for referral to the Attorney General. If appropriate, RWQCB staff should coordinate with the District Attorney or U.S. Attorney to determine whether criminal prosecution is warranted. In addition, such spills may constitute the unlawful disposal of hazardous waste pursuant to the Hazardous Waste Control Act (Health and Safety Code Section 25100 et seq.) and, in most cases,

should be investigated in conjunction with the California Department of Toxic Substances Control.

E. Spills of Non-hazardous Materials

Spills of materials that do not meet the formal criteria as being hazardous can still be highly toxic, such as some petroleum hydrocarbons or detergents, or of only limited toxicity, such as corn syrup. For this reason, such spills must be evaluated case-by-case for enforcement.

F. Solid Waste Facilities

Where a RWQCB has issued, or is likely to issue an enforcement action against a solid waste facility, it shall provide a statement to the local enforcement agency, the Integrated Waste Management Board, the air pollution control district or the California Department of Toxic Substances Control, if the violation involves the jurisdiction of that agency. This statement shall be provided at least 10 days prior to the date of issuance of an enforcement order which is not an emergency, within five days from the date of issuance of an enforcement order for an emergency, or within 15 days of the discovery of a violation of a state law, regulation, or term or condition of a solid waste facility's WDRs for a solid waste facility, which is likely to result in an enforcement action. The statement shall provide an explanation of and justification for the enforcement action, or a description of the violation (Public Resources Code (PRC) Section 45019).

The RWQCB shall inspect a solid waste facility within 30 days of receipt of an enforcement action or proposed enforcement action from one of the above agencies if such action stems from a complaint concerning a solid waste facility and if a water quality violation is at issue (PRC Section 45020).

- If a RWQCB receives a complaint concerning a solid waste facility, which is not within its jurisdiction, it must refer the complaint to the appropriate state agency within 30 days (PRC Section 45021).
- If a RWQCB receives a complaint concerning a solid waste facility, either directly or by referral from another state agency, it shall either take appropriate enforcement action, refer the complaint to the Attorney General, the district attorney, or city attorney, whichever is applicable, <u>or</u> provide, within 60 days, to the person who filed the complaint a written explanation as to why enforcement action is not appropriate (PRC Section 45022).
- RWQCB enforcement activities at solid waste facilities shall comply with the following (PRC Section 45020):
  - Enforcement activities shall eliminate duplication and facilitate compliance.
  - Facility operators must be notified before an ACL is assessed.
  - Prior to assessing an ACL, and upon the request of a solid waste facility operator, the RWQCB must meet with the operator to clarify regulatory requirements and to determine how the operator could come into voluntary compliance. The

operator may request a meeting with all agencies involved in the enforcement matter.

- The RWQCB must consider the factors listed in PRC Section 45016 in determining the appropriate enforcement action.

VII. ACL Procedures

The following provisions apply only to ACLs and do not apply to mandatory minimum penalties required pursuant to California Water Code sections 13385(h) and (i).

The RWQCB must make two important decisions in specifying the conditions of an ACL. First is the determination of the total liability considering the factors in law. These factors are described in the stepwise approach in section VII (A) below. Second is the determination of the appropriate distribution of that liability between payments to the SWRCB's Cleanup and Abatement Account (CAA), Compliance Projects (CPs), and Supplemental Environmental Projects (SEPs). This distribution is explained in Section VII(B).

A. Determination of the Total Liability

The California Water Code requires that the determination of the total liability include the consideration of a number of factors. Prior to issuing a complaint the RWQCB Executive Officer shall consider each factor. This consideration shall be documented in a staff report. If the RWQCB issues an ACL Order, the order shall contain findings explaining the Board's consideration of the factors. The documentation of elements such as the economic benefit, staff costs and avoided costs are necessary for the appropriate distribution of the total liability.

The California Water Code lists a number of factors that must be taken into consideration when setting ACLs. California Water Code section 13327, governing ACL amounts for a wide variety of violations, states that:

> [The Board] shall take into consideration the nature, circumstance, extent, and gravity of the violation or violations, whether the discharge is susceptible to cleanup or abatement, the degree of toxicity of the discharge, and, with respect to the discharger, the ability to pay, the effect on ability to continue in business, any voluntary cleanup efforts undertaken, any prior history of violations, the degree of culpability, economic savings, if any, resulting from the violation, and other matters as justice may require.

California Water Code section 13385(e), governing ACL amounts for violations subject to the CWA, has slightly different language, stating that:

> [The Board] shall take into account the nature, circumstances, extent, and gravity of the violation, and, with respect to the discharger, the ability to pay, any prior history of violations, the degree of culpability, economic benefit or savings, if any, resulting from the violation, and other matters that justice may require. At a minimum,

liability shall be assessed at a level that recovers the economic benefits, if any, derived from the acts that constitute the violation.

The California Water Code does not specify how these factors are to be weighed or combined when setting the actual dollar amount of an ACL. This section describes the procedure to be used to set ACL amounts based on the facts of the case. The steps in the procedure are shown in Table VII-1. This procedure applies to ACLs issued under both California Water Code section 13327 and California Water Code section 13385(e). The RWQCB staff should carefully document each step in the staff report for the ACL. The manner in which the RWQCB considers these factors for any given situation is up to the discretion of the RWQCB.

Table VII-1. Procedure to set ACL amounts

Step	Procedure
A. **Initial Liability**	Set an initial liability based on the extent and severity of the violation and the sensitivity of the receiving water. An initial liability should also be calculated for non-discharge violations.
B. **Beneficial Use Liability**	If possible, estimate the dollar value of any impacts of the violation on beneficial uses of the affected waters.
C. **Economic Benefit**	Estimate the economic benefit to the discharger. Economic benefit is any savings or monetary gain achieved by not preventing the violation.
D. **Base Amount**	The Base Amount a single amount that is a result of combining the figures derived from the first 3 steps. For many ACLs, the base amount will be the addition of the initial liability from step A and the economic benefit from step C because the calculation of the beneficial use liability may not be appropriate. For those instances where it is appropriate to calculate the beneficial use liability (step B), the initial liability may be reduced to reflect the extent that the impact of the violation is covered by the value estimated in Step B. The base amount reflects the extent and severity of the violation, its impact on beneficial uses, and takes away any monetary gain from the discharger.
E. **Adjustment for discharger's conduct**	Determine factors to adjust the Base Amount with respect to the conduct of the discharger's history of violations and other considerations. Apply these factors to the Base Amount from step D
F. **Adjustment for other factors**	Determine whether any other factors should be taken into consideration when setting the ACL amount. If appropriate, adjust the figure from Step E to include these factors.
G. **Staff Costs**	Estimate the SWRCB and RWQCB staff costs resulting from the violation. If appropriate, add this cost to the figure determined from steps A through F.
H. **Adjustment for ability to pay**	If appropriate, increase or reduce the figure from Steps A through G with respect to the discharger's ability to pay.
I. **Check against statutory limits**	Check the figure from steps A through H against the statutory maximum and minimum limits.

1. Step A. Initial Liability

Set an Initial Liability based on the nature, circumstances, extent, and gravity of the violation. This may include the consideration of information such as the pollutants contained in a discharge, the volume of the discharge, the sensitivity of the receiving water and its beneficial uses, known, suspected or threatened toxicity, threats to human health and the volume of the receiving water relative to the discharge. The way that this amount is calculated will depend on the type of violation. For spills, effluent limitation violations, and similar violations, the initial water quality liability can be based on a per-gallon charge.

For non-discharge violations such as late reports, failure to submit reports, and failure to pay fees, this initial water quality liability should be set considering the impact on the RWQCB's ability to effectively administer its water quality programs. These impacts include, but are not limited to, additional RWQCB staff costs beyond the normally required effort and the potential consequences of delayed clean-up, coordination, mitigation and enforcement response by the RWQCB due to late or omitted reports.

2. Step B. Beneficial Use Liability

Review the designated beneficial uses of the receiving water and determine whether the violation has resulted in any quantifiable impacts related to beneficial uses. Examples of quantifiable impacts are beach closures, fish kills, and reductions in wildlife populations.

To the extent that information is available, estimate the value of these impacts. It will rarely be possible to assign a value to all impacts on beneficial uses. However staff should review available information on values related to beneficial use of the receiving water and develop estimates of the impacts of the violation on these values.

For example, when a violation has resulted in a beach closure, this value could be estimated from a value per-person-per-visit of beach use, an estimate of how much the degradation in water quality has reduced this value and an estimate of the extent that the closure has reduced attendance.

3. Step C. Economic Benefit

Economic benefit is any savings or monetary gain achieved by not preventing the violation. In cases when the violation occurred as truly no fault of the discharger and it was demonstrated that the discharger exercised due care, there may be no economic benefit. In cases where the violation occurred because the discharger postponed improvements to a treatment system, failed to implement adequate control measures such as Best Management Practices (BMPs) or take other measures needed to prevent the violations, economic benefit could be estimated as follows:

a. Determine the actions that should have been taken to avoid the violation. Needed actions may have been capital improvements to the discharger's treatment system, implementation of adequate BMPs or the introduction of procedures to improve management of the treatment system.

b. Determine when these actions should have been taken.

c. Estimate the cost of these actions. The avoided costs may include expenditures that should have been made for capital improvements, adequate staffing, training, and the development of procedures and practices. If the discharger is now committed to implementing the actions needed to bring the discharger into compliance, the current costs should not be considered as part of the economic benefit but should be considered under Step F, "Other Factors", for a Compliance Project. The discharger's use of the money should be considered as part of the economic benefit under the next step d. The avoided ongoing costs such as needed additional staffing from the time determined under step b to the present should also be included in the economic benefit calculation.

d. Determine the value for use of the money. Convert the avoided costs to a present value at the time that the ACL is issued. This calculation reflects the fact that the discharger has had the use of the money that should have been used to pay to improve the treatment system. This calculation shall be done using the current version of USEPA's BEN computer program (the most recent version is accessible at http://www.swrcb.ca.gov/water_laws/index.html).

e. Determine whether the discharger has gained any other economic benefits. These may include income from continuing in production when equipment used to treat discharges should have been shut down or increased revenues gained as a result of competitive advantage.

f. The RWQCBs should not adjust the economic benefit for monetary efforts made by the discharger to abate the effects of the discharge.

On a case by case basis and to the extent that the information is available these figures should be estimated and used to calculate economic benefit. Any compound interest calculations must be done using USEPA's BEN computer program which is available at http://www.swrcb.ca.gov.

4. Step D. Base Amount

The Base Amount is the sum of the Initial Liability or the Beneficial Use Liability or a combination of the Initial Liability and the Beneficial Use Liability and the Economic Benefit. When it is appropriate to calculate the Beneficial Use Liability, the RWQCBs should assess the extent to which the Beneficial Use Liability represents the entire harm resulting from the violation. The RWQCBs may, at their discretion, find it appropriate to combine the amounts from Steps A and B in a way that reflects the significance of the impacts quantified in Step B relative to the total impacts of the violation.

The way that the Initial Liability and the Beneficial Use Liability should be combined will depend on how the violation harms the beneficial uses of the receiving waters and the extent to which this harm has been quantified. For example, a sewage spill will typically result in a wide variety of impacts, such as fish kills, degradation of wildlife habitat, and beach closures. For a sewage spill to the ocean in an urban area with high beach use, impacts on beach recreation may represent most of the harm resulting from the spill. If it is possible to estimate the value of the lost beach recreation in step B, it is appropriate to take this value and add it to some portion of the Initial Liability amount to reflect the total impact.

For a sewage spill contaminating a beach in a remote area, where beach use is relatively low, impacts on beach use are less important than other impacts, such as degradation of wildlife habitat and harm to a pristine environment. In such a case, the combined liability (steps A and B) should be based more heavily on the Initial Liability, because the impacts quantified in step B are less significant relative to the entire impacts of the violation.

Next, add the liability from steps A and/or B to the economic benefit from Step C to give the Base Amount. This calculation gives an amount that is the minimum appropriate to the violation. It reflects the nature, circumstances, extent, and gravity of the violation, and its impact on beneficial uses including toxicity, while taking away any economic benefit or savings to the discharger considering any expenditures associated with voluntary cleanup if appropriate.

5. Step E. Conduct of the Discharger

The Base Amount from Step D must then be adjusted to reflect the conduct of the discharger. This adjustment reflects factors such as the degree of culpability of the discharger, any voluntary cleanup efforts undertaken and the discharger's history of violations. This adjustment can be made by determining values for the four factors in Table VII-2, and using them to determine a conduct factor that is applied to the Base Amount. The RWQCB may apply the various conduct factors using percentages. A percentage less than 100 percent may be appropriate for a discharger that made exemplary efforts such as voluntary cleanup. Percentages greater than 100 percent are appropriate for dischargers that demonstrated less than exemplary behavior such as delaying notification of a spill. Large multiplier percentages 200 - 500 percent may be appropriate for cases involving falsification of data or other deliberate acts. This calculation is:

$$ACL = Base\ Amount \times CF1 \times CF2 \times CF3 \times CF4$$

Table VII-2. Conduct Factors to adjust ACLs

Factor	Adjustment for
Control Factor (CF1)	Amount of control that the discharger had over the discharge
Notification Factor (CF2)	Extent to which the discharger reported the violation as required by law or regulation.
Cooperation Factor (CF3)	Extent to which the discharger cooperated in returning to compliance and correcting environmental damage, including any voluntary cleanup efforts undertaken.
History factor (CF4)	Previous violations

6. Step F. Other Factors

If it is determined that there were avoided capital costs under the calculation of economic benefit and that the discharger is committed to take the necessary actions, the RWQCB may include the amount of those costs under "other factors" in the ACL. The RWQCB can also suspend that amount contingent upon implementation of a Compliance Project.

If the RWQCB believes that the amount determined using Steps A through E is inappropriate, the amount may be adjusted. Examples of circumstances warranting an adjustment under this step are:

- The discharger publicized the violation and the subsequent enforcement actions in a way that encourages others to violate water quality laws and regulations.
- The threat to human health or the environment was so egregious that the preceding factors did not, in the opinion of the RWQCB, adequately address this violation.

If such an adjustment is made, the reasons for the extent and direction of the adjustment must be noted in the administrative record.

7. Step G. Staff Costs

Staff costs are one of the "other factors that justice may require", and should be estimated when setting an ACL. Staff should estimate the cost that investigation of the violation and preparation of the enforcement action(s) has imposed on state government agencies. Staff costs should be added to the amount calculated from the previous steps.

8. Step H. Ability to Pay

The procedure in Steps A through G gives an amount that is appropriate to the extent and severity of the violation, economic benefit and the conduct of the discharger. This amount may be reduced or increased based on the discharger's ability to pay.

The ability of a discharger to pay an ACL is limited by its revenues and assets. In most cases, it is in the public interest for the discharger to continue in business and bring operations into compliance. If there is strong evidence that an ACL would result in widespread hardship to the service population or undue hardship to the discharger, it may be reduced on the grounds of ability to pay. The RWQCBs may also consider increasing an ACL to assure that the enforcement action would have a similar deterrent effect for a business or public agency that has a greater ability to pay.

a. Businesses

Normally, an ACL should not seriously jeopardize the discharger's ability to continue in business. The discharger has the burden of proof of demonstrating lack of ability to pay and must provide the information needed to support this position. This adjustment can be used to reduce the ACL to the highest amount that the discharger can reasonably pay and still bring operations into compliance. The downward adjustment for ability to pay must be made only in cases where the discharger is cooperative and has the business ability and the intentions to bring operations into compliance. If the violation occurred as a result of deliberate or malicious conduct, or there is reason to believe that the discharger can not or will not bring operations into compliance, the ACL must not be adjusted for ability to pay.

The RWQCBs may also consider increasing the ACL because of a business's ability to pay. RWQCBs should consider other ACLs for similar violations taken elsewhere in the Region or the State and adjust the amount up or down according to a discharger's ability to pay. This type of adjustment may serve to "level the playing field". For example, in order to have an equivalent deterrent effect for similar violations, the ACL for a Fortune 500 company should be significantly greater than one for a small business.

b. Public Agencies

ACLs paid by cities, sanitation districts and other public agencies are ultimately paid by their service populations, usually by taxes or user fees. The RWQCB may consider adjusting the total liability for cases of hardship or increasing the ACL if the agency has a large rate base and it is appropriate to increase the ACL to assure a similar deterrent effect for similar violations.

9. Step I. Statutory Maximum and Minimum Limits

The ACL must be checked against the statutory maximum and minimum limits to ensure that it is in compliance with the appropriate section of law. The maximum amount for an ACL issued under California Water Code section 13385 is $10,000 for each day in which a violation occurs plus $10 per gallon for amounts discharged but not cleaned up in excess of 1,000 gallons. The statutory maximum amounts for ACLs issued under California Water Code section 13261 are summarized in Table IV-1.

California Water Code section 13385, which applies to discharges regulated pursuant to the CWA, was amended effective January 1, 2000 to state that "At a minimum, liability shall be assessed at a level that recovers the economic benefits, if any, derived from the acts that constitute the violation". Therefore, for such violations occurring on or after January 1, 2000, the minimum amount for an ACL is the economic benefit.

It is the policy of the SWRCB that all ACLs shall be assessed at a level that recovers the economic benefit.

B. Distribution of an ACLs Liability

An ACL action may distribute the total, proposed liability determined above to three types of discharger-expenditures: implementation of CPs; implementation of SEPs; and cash payments to the State Cleanup and Abatement Account, including staff costs. If the

ACL action distributes liability to CPs or SEPs, it shall document that the amount of liability suspended is equal to the cost of implementing the CPs and/or SEPs and shall specify the date on which the CPs and/or SEPs are to be completed. The ACL action shall specify the amount of liability that shall be immediately due to the State Cleanup and Abatement Account. The cash liability shall, at a minimum, include the staff costs associated with the investigation of the violations and preparation of the ACL.

1. Compliance Projects (CPs)

ACL actions are intended to address past violations. If the underlying problem has not been corrected, the cost of returning to compliance constitutes an avoided cost (and thus an economic benefit) until the necessary improvements are actually implemented. Under these circumstances, the RWQCB may suspend a portion of the liability to compel future work by the discharger to address problems related to the violation. Compliance Projects (CPs) are projects designed to bring the discharger back into compliance in a timely manner.

a. Examples of CPs

CPs may include construction of new facilities, upgrade or repair of existing facilities, adding staff, training, studies, and the development of procedures.

b. CP Qualification Criteria

1) CPs are projects that are designed to bring the discharger back into compliance in a timely manner.
2) CPs are not SEPs
3) CPs shall have clearly identified project goals, costs, milestones, and completion dates and these shall be specified in the ACL action.

c. ACL Actions Allowing CPs

1) Either the RWQCB or the discharger may recommend specific CPs that could be included in the ACL action.
2) The ACL action shall only suspend the portion of the total liability contingent upon completion of a CP(s) that is equal to the discharger's economic benefit of the avoided costs.
3) CPs that are greater than one year shall have at least annual reporting requirements.
4) If the discharger expends at least the amount suspended and completes the CP by the specified date, the suspended amount is permanently suspended.
5) If the CP is not completed on the specified date the amount suspended becomes due and payable to the CAA.

2. Supplemental Environmental Projects (SEPs)

Supplemental Environmental Projects (SEPs) are projects that enhance the beneficial uses of the waters of the State, provide a benefit to the public at large, and that, at the time they are included in an ACL action, are not otherwise required or would be greatly accelerated by implementing the project. California Water Code section 13385(h)(3) allows limited use of SEPs associated with mandatory minimum penalties. In addition, the SWRCB supports the inclusion of SEPs in ACL actions, so long as these projects meet the criteria listed below.

a. <u>Examples of Supplemental Environmental Projects</u>

- Pollution Prevention
- Environmental Restoration (e.g., projects that involve the restoration or enhancement of wildlife and aquatic habitat)
- Environmental Auditing (e.g., projects that involve studies relevant to the discharge)
- Public Awareness (e.g., industry specific, public-awareness activity, or community environmental education projects such as watershed curriculum, brochures, television public service announcements, etc.)
- Watershed Assessment (e.g., citizen monitoring coordination and facilitation)
- Watershed Management Facilitation Services
- Non-Point Source Program Implementation

b. <u>SEP Qualification Criteria</u>

- An SEP should only consist of measures that go above and beyond the obligation of the discharger. For example, sewage pump stations should have appropriate reliability features to minimize the occurrence of sewage spills in that particular collection system. The installation of these reliability features following a pump station spill would not qualify as an SEP.
- The SEP should lead to improved water quality and enhanced support of beneficial uses of waters of the State.
- The SEP shall not directly benefit the SWRCB or RWQCB functions or staff. For example, SEPs shall not be gifts of computers, equipment, etc. to the SWRCB or RWQCB.
- The SEP shall not be an action, process or product that is ***required*** by any rule or regulation of any entity (e.g., local government, California Coastal Commission, United States Environmental Protection Agency, United States Army Corps of Engineers, etc.).
- The SEP shall contain specific performance standards, including milestones for achievement, and identified measures or indicators of performance. The ACL action shall specify that the discharger shall meet these standards, milestones and indicators.
- The SEP should, when appropriate, include documented support by other resource agencies, public groups and impacted persons.

- The SEP should, when appropriate, document that the project complies with the California Environmental Quality Act.

c. <u>ACL Actions Allowing SEPs</u>

- [For all ACL actions pursuant to any relevant California Water Code section other than Section 13385.] The discharger may propose to conduct an SEP in exchange a portion of the proposed liability, exclusive of the amount specified for a CP, in the ACL action. If the discharger opts to perform a SEP, the ACL action shall require the discharger to pay the remainder proposed liability, exclusive of the amount specified for a CP, to the State Cleanup and Abatement Account.
- The ACL action shall require the discharger to provide at least one progress report to the SWRCB or RWQCB at the completion of the SEP.
- The ACL action shall require the discharger to provide the RWQCB a post-project accounting of expenditures.
- If an SEP is accepted in an ACL action, the discharger shall hire an independent management company, which reports solely to the RWQCB, to audit implementation of the SEP. The company shall evaluate compliance with performance measures and make recommendations to the RWQCB about the successful completion of the SEP prior to the deadline(s) to complete.
- If the final cost of the successfully completed SEP is less than the amount suspended for completion of the SEP in the ACL action, the discharger shall remit the difference to the State Cleanup and Abatement Account.
- If the SEP is not successfully completed by the date specified in the ACL action, the discharger shall pay the amount that was suspended to the State Cleanup and Abatement Account.
- If the discharger successfully completes the SEP in a time specified, the portion suspended for the SEP will be permanently suspended.
- Because the RWQCB loses the ability to amend an ACL order, the ACL order shall contain reasonable milestones and compliance dates and the RWQCB should consider including a force majeure clause.

d. <u>Public Process</u>

The SWRCB will establish procedures to develop lists of candidate projects. The list of candidate projects shall be made available on the Internet in the form of a database containing information on candidate projects, completed projects, and in-progress projects. At a minimum, the RWQCBs shall provide public notice of adoption of ACLs Orders that include SEPs. In cases where the ACL includes a SEP and covers violations of the CWA, the RWQCBs shall provide a period for public comment prior to adoption. All ACL complaints that have been settled by the Executive Officer, with or without SEPs, shall be placed as an information item on the next, feasible agenda for the RWQCB.

VIII. DISCHARGER SELF-AUDITING

It is desirable to encourage self-auditing, self-policing, and voluntary disclosure of environmental violations by dischargers. Such self-auditing and voluntary disclosure of violations shall be considered by the Boards when determining enforcement actions and in appropriate cases may lead to a determination to forego or lessen the severity of an enforcement action. Falsification or misrepresentation of such voluntary disclosures shall be brought to the attention of the appropriate RWQCB for possible enforcement action.

IX. ENFORCEMENT REPORTING BY RWQCBS

In order to ensure greater consistency in the reporting by the RWQCBs on violations and enforcement actions, the enforcement reports for all Regions will be standardized. These reports will include a listing of facilities with a water quality violation during the reporting period or unresolved from a previous reporting period, including violations without a RWQCB response. This listing shall include at least the following information:

- The date of violation;
- An identification whether the violation is considered to be significant (see Section III);
- The RWQCB response, if any;
- The date of the response;
- The corrective action taken by the discharger, at least in cases of significant violations; and
- A listing of all previous violations for the facility which occurred in the previous 12 months and the associated RWQCB response.

The enforcement reports will be presented to the RWQCBs on an interval no greater than quarterly. The report format will be the format that is produced by the State Water Information Management (SWIM) data system and the RWQCBs will utilize the SWIM data system to track and monitor their violations and enforcement activities. Utilization of the SWIM data system by the Regions is essential in order for the SWRCB to comply with California Water Code section 13385 (m) which requires statewide reporting of violations to the Legislature.

A. Summary Violation and Enforcement Reports

All RWQCBs shall produce standard quarterly reports addressing significant violations. The SWRCB will specify the format of the summary reports.

B. Spill Reporting

All spills shall be entered into the Sanitary Sewer Overflow/Spills Module of the SWRCB's SWIM data system. In order to achieve consistent reporting of spills from regulated discharges all new and revised requirements and permits shall at a minimum contain the language requiring reporting of spills consistent with Table IX-1 below.

SUMMARY OF SPILL REPORTING REQUIREMENTS
TABLE IX-1

TYPE	VOLUME	DISCHARGE POINT	REPORTING PERIOD
Sewage	any	Waters of U.S./Impairment of Use	ASAP, but no more than 24 hours
Sewage	< 1000 Gals.	Soil	Quarterly
Sewage	=>1000 Gals.	Soil	ASAP, but no more than 24 Hours
Hazardous Materials	Any	Waters of U.S.	ASAP, but no more than 24 hours
Hazardous Materials	Any amount that poses a threat to beneficial uses.	Soil	ASAP, but no more than 24 hours
Oil	Any amount that produces a sheen.	Waters of U.S.	ASAP, but no more than 24 Hours
Non-hazardous materials (e.g., dirt, winery wastes, non-hazardous leachate, etc.)	Any amount that poses a threat to beneficial uses.	Soil or waters of the U.S.	Quarterly

X. POLICY REVIEW AND REVISION

It is the intent of the SWRCB that this policy be reviewed and revised, as appropriate, at least every five years.

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

In Reply Refer To:
Mail Stop 412 or
Mail Stop 415

November 27, 2000

OFFICE OF WATER QUALITY TECHNICAL MEMORANDUM NO. 2001.03
OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM NO. 2001.03

Subject: Collection and Use of Total Suspended Solids Data

USGS Policy on Collection and Use of Total Suspended Solids Data:

1. The use of Total Suspended Solids data (TSS, parameter code 00530) resulting from the analysis of water samples to determine the concentration of suspended material in water samples collected from open channel flow and calculations of fluxes based on these data is not appropriate. Collection of samples to determine TSS requires concurrent collection of samples for suspended sediment concentration (SSC) analysis. Concurrent SSC analysis can only be discontinued after it is conclusively documented in a published report that the TSS data, on a site-by-site basis, can adequately represent SSC data over the whole range of flows that can be expected.

2. The SSC analytical method, ASTM D 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples (ASTM, 1999), is the USGS standard for determining concentrations of suspended material in surface water samples. This method is used by all USGS sediment laboratories, and by cooperating laboratories certified to provide suspended-sediment data to the USGS.

Background:

An important measure of water quality is the amount of material suspended in the water. The USGS has traditionally used measurements of suspended-sediment concentration as the most accurate way to measure the total amount of suspended material in a water sample collected from the flow in open channels. Another commonly used measurement of suspended material is the TSS analytical method. This method was originally developed for use on wastewater samples, but has been widely used as a measure of suspended material in stream samples because it is mandated or acceptable for regulatory purposes and is an inexpensive laboratory procedure. Using the TSS analytical method (parameter code 00530) to determine concentrations of suspended material in open channel-flow can result in unacceptably large errors and is fundamentally unreliable.

Summary of Recent Studies:

Studies on the accuracy of the SSC analytical method by ASTM (1999) and the USGS Branch of Quality Systems (Gordon and others, 2000) have shown that the SSC analysis represents an accurate measure of the concentration of the suspended sediment in a sample. Other measurements such as TSS, turbidity, and data obtained from optical backscatter instruments are often used as surrogates for suspended sediment and are often less expensive to collect and (or) analyze and some may be collected on a near-continuous basis. However, proper use of these surrogate measurements of suspended material requires that a relationship between SSC and the surrogate be defined and documented for each site at which the data are collected.

Differences between the TSS and SSC analyses were investigated using 3,235 paired TSS and SSC samples provided by eight USGS Districts (Gray and others, 2000), and with 14,466 data pairs from the USGS's NWIS data base (Glysson and others, 2000). The findings of these studies can be summarized as follows:

1. The TSS analysis is normally performed on an aliquot of the original sample. The difficulty in withdrawing an aliquot from a sample that truly represents suspended material concentration leads to inherent variability in the measurement. By contrast, SSC analysis is performed on the entire sample, thus measuring the entire sediment mass. If a sample contains a substantial percentage of sand-size material - more than about 25 percent - then stirring, shaking, or otherwise agitating the sample before obtaining a subsample will rarely produce an aliquot representative of the suspended material and particle-size distribution of the original sample.

2. TSS methods and equipment differ among laboratories, whereas SSC methods and equipment used by USGS sediment laboratories are consistent, and are quality assured by the National Sediment Laboratory Quality Assurance Program (OSW Technical Memorandum 98.05; Gordon and others, 2000).

3. Results of the TSS analytical method tend to produce data that are negatively biased by 25 to 34 percent with respect to SCC analyses collected at the same time and can vary widely at different flows at a given site. The biased TSS data can result in errors in load computations of several orders of magnitude.

Analysis of paired data for TSS and SSC (Glysson and others, 2000) indicates that in some cases, it might be possible to develop a relation between SSC and TSS at a given site. At least 30 paired sample points, evenly distributed over the range of concentrations and flows encountered at the site, would be needed to define such a relationship. There is no reliable, straightforward way to adjust TSS data to estimate suspended sediment without corresponding SSC data.

Because the TSS analytical method is widely used outside of the USGS for the determination of suspended-material concentrations in water samples for open channel flow, and because the TSS analysis is specified in several States' water-quality criteria standards for sediment, it would be appropriate for USGS District offices to share this information with their cooperators. The Offices of Water Quality and Surface Water are passing this information on to the U.S. Environmental Protection Agency's Office of Water and to other Federal agencies that are involved in using sediment data. For questions or additional information, contact Doug Glysson (OWQ, gglysson@usgs.gov) or John Gray (OSW, jrgray@usgs.gov).

References:

ASTM, 1999, D 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, Annual Book of Standards, Water and Environmental Technology, 1999, Volume 11.02, p 389-394.

Glysson, G. D., J. R. Gray, and L. M. Conge, 2000, "Adjustment of Total Suspended Solids Data for Use in Sediment Studies," in the Proceeding of the ASCE's 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management, July 30 – August 2, 2000, Minneapolis, MN, 10 p. *

Gordon, J. D., Newland, C. A., and Gagliardi, S. T., 2000, Laboratory Performance in the Sediment Laboratory Quality-Assurance Project, 1996-98: U. S. Geological Survey Water-Resources Investigations Report 99-4184, 69 p.

Gray, J. R., G. D. Glysson, L. M. Turcios, and G. E. Schwarz, 2000, Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, U.S. Geological Survey Water-Resources Investigations Report 00-4191, 14 p. *

U.S. Geological Survey, 1998, A National Quality Assurance Program for Sediment Laboratories Operated or Used by the Water Resources Division: Office of Surface Water Technical Memorandum No. 98.05, accessed November 13, 2000 from URL http://water.usgs.gov/admin/memo.

(* References are on-line at URL http://water.usgs.gov/osw/techniques/sediment.html)

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This memorandum does not supersede any other technical memorandum.

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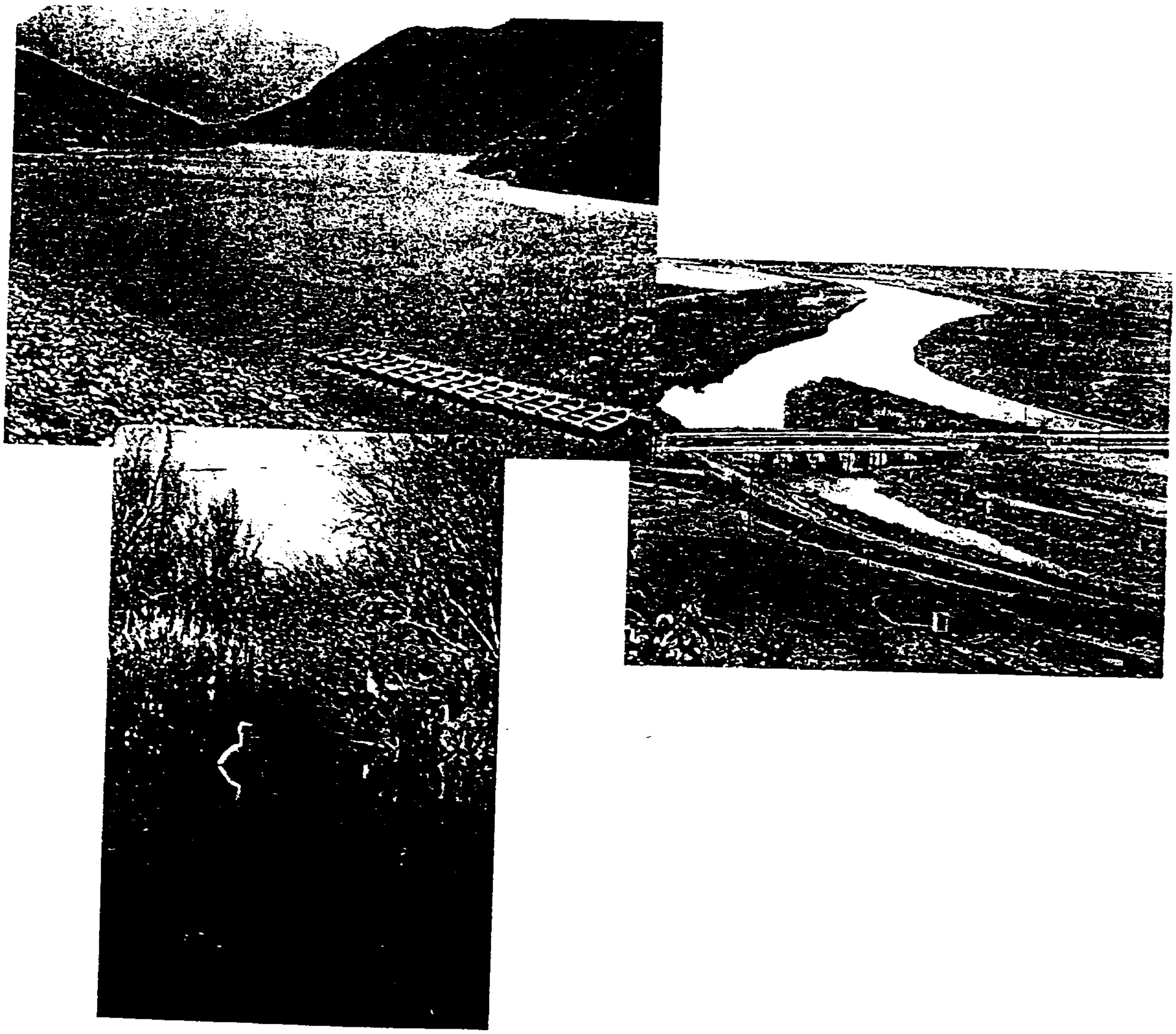
Regional Water Quality Control Board
Los Angeles Region



Watershed Management Initiative Chapter
December 2000

ADMINISTRATIVE RECORD
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TABLE OF CONTENTS

EXECUTIVE SUMMARY I.

SECTION 1 .INTRODUCTION 1-1

SECTION 2 .ACTIVITIES ORGANIZED ON A WATERSHED BASIS 2-1

2.1 SANTA CLARA RIVER WATERSHED 2.1-1

2.2 CALLEGUAS CREEK WATERSHED 2.2-1

2.3 DOMINGUEZ CHANNEL AND LOS ANGELES/LONG BEACH HARBORS WMA 2.3-1

2.4 SANTA MONICA BAY WMA 2.4-1

2.5 LOS ANGELES RIVER WATERSHED 2.5-1

2.6 SAN GABRIEL RIVER WATERSHED 2.6-1

2.7 LOS CERRITOS CHANNEL AND ALAMITOS BAY WMA 2.7-1

2.8 THE CHANNEL ISLANDS WMA 2.8-1

2.9 VENTURA RIVER WATERSHED 2.9-1

2.10 MISCELLANEOUS VENTURA COASTAL WMA 2.10-1

SECTION 3 . REGIONWIDE ACTIVITIES 3-1

SECTION 4. APPENDICES 4-1

EXECUTIVE SUMMARY
LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD WATERSHED MANAGEMENT INITIATIVE CHAPTER
December 2000

OVERVIEW

Water resource protection efforts of the State Water Resources Control Board and the Regional Water Quality Control Boards are guided by a five year Strategic Plan (last updated in 1997). A key component of the Strategic Plan is to utilize a watershed management approach for water resources protection.

To protect water resources within a watershed context, a mix of point and nonpoint source discharges, ground and surface water interactions, and water quality/water quantity relationships must be considered. These complex relationships present considerable challenges to water resource protection programs. The State and Regional Boards are responding to these challenges within the context of our organization's Watershed Management Initiative (WMI). The WMI is designed to integrate various surface and ground water regulatory programs while promoting cooperative, collaborative efforts within a watershed. It is also designed to focus limited resources on key issues and use sound science.

Previously, State and Regional Board programs tended to be directed at site-specific problems. This approach was reasonably effective for controlling pollution from point sources. However, with diffuse nonpoint sources of pollutants, a new regulatory strategy was needed. The WMI uses a strategy to draw solutions from all interested parties within a watershed, and to more effectively coordinate and implement measures to control both point and nonpoint sources.

For the initial implementation of the WMI, during the late 1990s, each Regional Board identified the watersheds in their Region, prioritized water quality issues, and developed watershed management strategies. These strategies and the State Board's overall coordinating approach to WMI are contained in the *Integrated Plan for Implementation of the WMI* which is updated annually. In following years, the Regional Boards have continued to build upon their early efforts to utilize this approach. The full version of our WMI Chapter outlines our ongoing efforts to continue implementation of the WMI.

The Los Angeles Regional Board and Watershed Management

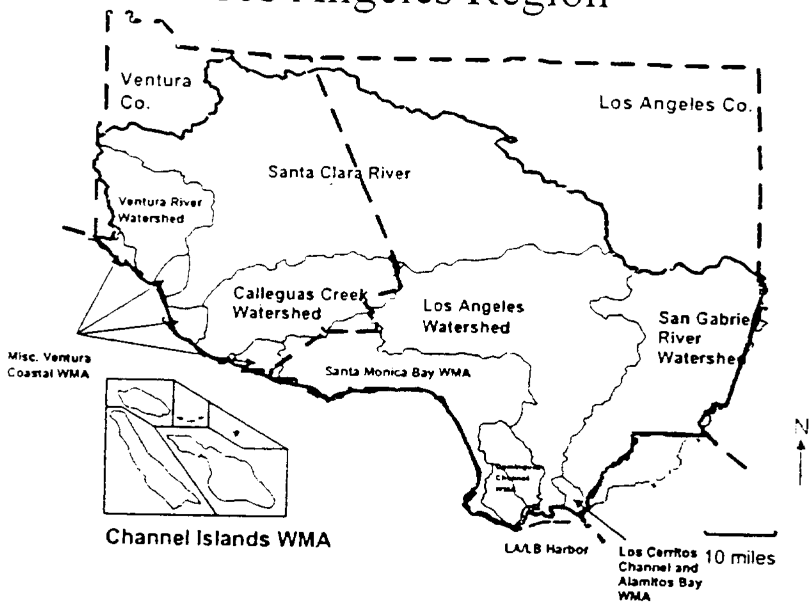
The Los Angeles Region has jurisdiction over all coastal drainages flowing to the Pacific Ocean between Rincon Point (on the coast in western Ventura County) and the eastern Los Angeles County line, as well as the drainages of five coastal islands (Anacapa, San Nicolas, Santa Barbara, Santa Catalina, and San Clemente). The Regional Board's jurisdiction also includes all coastal waters within three miles of the continental and island coastlines.

The Los Angeles Region is the State's most densely populated and industrialized region. Over 1,000 discharges of wastewater from point sources in this Region are regulated by the Los Angeles Regional Board. Over 700 of these point source discharges are discharged to surface waters, and are regulated under the National Pollutant Discharge Elimination System (NPDES). In addition, the Regional Board prescribes Waste Discharge Requirements (WDRs) for the remaining discharges, which are primarily to ground waters and landfills. However, the quality of many waters continue to be degraded from pollutants discharged from diffuse and diverse nonpoint sources. Future success in reducing pollutants from nonpoint sources and achieving additional reductions in pollutants from point sources requires a shift to a more geographically-targeted approach.

Our watershed management approach integrates activities across the Regional Board's many diverse programs, particularly permitting, planning, and other surface-water oriented programs which have tended to operate somewhat independent of each other. This approach enables us to better assess cumulative impacts of pollutants from all (point and nonpoint) sources, and more efficiently develop watershed-specific solutions that balance the environmental and economic impacts of our actions.

We have designated ten watershed management areas in the Los Angeles Region as shown in the figure below.

Watershed Management Areas of the Los Angeles Region



Initially, implementation of watershed management in the Los Angeles Region occurred in phases over a seven-year cycle for our pilot watersheds Ventura River and Calleguas Creek. We are now shifting to a five-year cycle to be in line with the standard permit life (of an NPDES permit) and to equalize workloads over the years. This shift in our watershed cycle is illustrated in the table on the next page. The majority of permit-related tasks such as permit renewals/revisions and regional monitoring program development as well as preparation of state of watershed reports, will occur during the first approximately twelve months of the watershed's five-year cycle. Much of the rest of the five-year cycle will be spent developing and implementing, with the input of stakeholders, measures for management of more complex pollutants from point and/or nonpoint sources. Many of the region's TMDLs will be implemented during the second cycle of permit renewals.

It should be pointed out that the involvement of stakeholders is critical to the success of watershed management; however, the process to involve stakeholders demands more of regulators in terms of public outreach, education, and consensus building.

Permit Timeline for Watershed Management Initiative

Santa Clara River Calleguas Creek	FY 2001/02
Dominguez Channel-LA/LB Harbor	FY 2002/03
Santa Monica Bay	FY 2003/04
Los Angeles River	FY 2004/05
San Gabriel River Los Cerritos Channel Channel Islands	FY 2005/06
Ventura River Misc. Ventura Coastal Santa Clara River Calleguas Creek	FY 2006/07
Dominguez Channel-LA/LB Harbor	FY 2007/08

NPDES permits in the Los Angeles Region are organized and scheduled by watershed. This workload must be integrated with that required under backlog reduction efforts or other regulatory or legislative requirements. Preliminary "State of the Watershed Reports" are prepared by watershed "teams" composed of permit writers, planning, TMDL, and nonpoint source program personnel, and those involved with groundwater protection.

The Watershed Management Initiative Chapter

This document is the fifth iteration of what we call our "Chapter" which is our Region's chapter of the WMI document for the whole state. The participants in implementation of the WMI in California (the nine Regional Boards, State Board, and USEPA) were asked in 1996 to begin preparation of a document which identified priorities and resource needs, across programs, in a watershed context. The Chapter is currently used both as an outreach and as a planning tool to identify the Region's priorities over the upcoming two fiscal years (FYs) and where we should spend our baseline resources, as well as where we need additional resources. The Chapter is organized into sections including the Introduction, Watershed Sections, and Region-wide Section. Included in each Watershed Section is an overview of that watershed, a description of its water quality concerns and issues, past significant Regional Board activities in the watershed, current (funded) activities, near-term (usually unfunded) activities that would benefit the watershed, and activities which may happen on a longer time-scale (usually unfunded). The Region-wide Section includes a description of activities not easily associated with particular watersheds.

Programs and Funding Under WMI

Programs covered under WMI include core regulatory (e.g., NPDES), monitoring and assessment, basin planning and water quality standards, watershed management, wetlands, TMDLs, 401 certifications, groundwater (as appropriate), and nonpoint source management activities (many of these programs also have region-wide components). It turns out most of our highest priority needs fall into areas that have little to no funding. **Areas with particular shortages include nonpoint source management (e.g., we see a need for an additional 14.0 PYs for FY00/01)**, CEQA review, monitoring and assessment, basin planning, **401 certifications (the statewide needs analysis from FY 00/01 indicated a shortfall** of 13.9 PYs), stormwater, and more than minimal work on NPDES pretreatment, enforcement, compliance, and monitoring report review. A majority of any additional monies that may become available would be dedicated to these programs in the targeted watersheds (then non-targeted watersheds) as well as allocated to upcoming TMDLs occurring throughout the Region. **For example, in FY00/01, we see a need for an additional 8.8 PYs to conduct TMDL work**. This watershed effort, which itself has

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consumed a lot of limited staff resources, will hopefully result in resource flexibility and augmentation to address these deficiencies.

Integration of Multiple Mandates Under WMI

While the Watershed Management Initiative strives to integrate and coordinate the various Regional and State Board programs and address the highest priority funding needs for those programs, there is also need to respond to and accommodate priorities established by the individual Regional and State Boards' members, priorities established prior to the WMI which run on their own timelines, legal or legislative mandates, or other new mandates which may affect the way the WMI is implemented in a Region. It is important to re-state here that the WMI is not a new program but rather a way to describe our approach to integrating existing and newly evolving programs and mandates.

For example, a high priority statewide mandate is management of nonpoint source pollution. High priority Regional Board activities include implementation of an effective enforcement strategy, development of a septic tank policy initiative, development and implementation of a strategy to assess nonpoint source loadings TMDLs, and better communication and coordination of Board programs and policies through improved outreach. More information is included in the Introduction of the full chapter. It is clear many of the Regional Board high priority activities are of primary importance in fulfilling not only the WMI but also the nonpoint source management initiative and other mandates.

However, some mandates present challenges to fully implementing watershed management. These include recent USEPA, State Board, and legislative requirements for reducing permit backlog, conflicts with the timing of scheduled TMDLs, lengthy delays incurred by the public processes e.g., hearings, workshops), ands insufficient funding or staff.

SUMMARY OF SIGNIFICANT WATERSHED ISSUES

The Region encompasses ten Watershed Management Areas (WMAs) which are the geographically-defined watershed areas where the Regional Board implements the watershed approach. These generally involve a single large watershed, within which exists smaller subwatersheds. However, in some cases they may be an area that does not meet the strict hydrologic definition of a watershed (e.g., several small Ventura coastal waterbodies in the region are grouped together into one WMA). Watersheds in the strictest sense are geographic areas draining into a river system, ocean or other body of water through a single outlet and includes the receiving waters. They are usually bordered, and separated from other watersheds, by mountain ridges or other naturally elevated areas.

Many of the watersheds in this Region range over large areas that are highly diverse. A Designated Wilderness Area may occur in one part of a watershed while extensive development dominates another part and possibly agriculture in yet different area of the watershed. This fact results in a great diversity of issues of concern to this agency in any particular watershed with the concomitant need to balance priorities among existing stakeholders. The following summarizes significant watershed issues in our watershed management areas. More detail may be found by consulting the full version of the WMI Chapter.

Watershed Management Areas
Significant Watershed Issues

1) Ventura River Watershed
- Eutrophication, especially in estuary
- TDS concerns in some subwatersheds
- One major discharger (POTW)
- Industrial storm water – 27 dischargers
- Impediments (dams, diversions) to steelhead trout migration
- Impairments: DDT, algae, diversions, selenium, other metals, trash
- Currently scheduled TMDLs: eutrophication FY04/05

2) Miscellaneous Ventura Coastal WMA
The harbors
- Accumulation of metals, PCBs, and historic pesticides in sediment and tissue
- Considerable marine life subject to impacts
- Impairments: DDT, PCBs, PAHs, metals, TBT, coliform
- Currently scheduled TMDLs: zinc FY04/05

The wetlands and coast
- Historic pesticide contamination
- Loss of quality habitat
- Impacts from oil spills and agriculture
- Use by endangered species
- Impairments: historic pesticides and effects, coliform
- Currently scheduled TMDLs: coliform FY01/02

3) Santa Clara River Watershed
- High quality natural resource
- Four POTWs
- Industrial storm water – 103 dischargers
- Construction storm water – 310 dischargers
- Impacts from exotic vegetation
- Impacts from agriculture
- Increasing urbanization, flows, and channelization in upper watershed; impacts on middle and lower watershed
- Impairments: nitrogen and effects, salts, coliform, trash, historic pesticides
- Currently scheduled TMDLs: chloride FY01/02, nitrogen FY02/03, eutroph. and trash FY04/05, coliform FY05/06

4) Calleguas Creek Watershed
- Six POTWs
- Industrial storm water – 82 dischargers
- Construction storm water – 100 dischargers
- Highly modified watershed
- Impacts from agriculture and naval facility
- Sediment inputs to Mugu Lagoon, one of the largest wetlands in southern California
- Competing urban uses; development pressures, particularly in upper watershed
- Severe lack of benthic and riparian habitat in watershed
- Impairments: nitrogen and effects, water-soluble pesticides and effects, salts, historic pesticides, PCBs, siltation, selenium, mercury, other metals, trash
- Currently scheduled TMDLs: chloride FY00/01, nitrogen FY01/02, other salts and water-soluble pesticides FY03/04, PCBs and historic pesticides FY04/05, metals FY05/06

5) Dominguez Channel/LA-LB Harbor WMA
- One POTW, two generating stations, six refineries
- Industrial storm water – 415 dischargers
- Historical deposits of DDT and PCBs in sediment
- Discharges from POTW & refineries
- Spills from ships and industrial facilities
- Leaching of contaminated groundwater
- Stormwater runoff
- Impairments: metals, PCBs, PAHs, historic pesticides, coliform, trash, nitrogen
- Currently scheduled TMDLs: coliform FY01/02

6) Santa Monica Bay WMA
- Key recreational resource (beaches)
- Three POTWs, one refinery, and three generating stations
- 21 minor discharges
- General permits – 166 dischargers
- Industrial storm water – 147 dischargers
- Construction storm water – 107 dischargers
- Impairments: mercury, selenium, other metals, historical pesticides, PAHs, PCBs, nitrogen, coliform, trash, TBT, habitat alteration, exotic vegetation, salts

Coastline
- Acute health risk associated with swimming in runoff-contaminated surfzone waters
- Chronic risk associated with consumption of seafood in areas impacted by DDT and PCB contamination
- Reduction of loadings from the two major POTWs in light of projected population increases
- Other impacts from urban runoff/storm water
- Historic deposits of DDT and PCBs in sediment
- Loadings of pollutants from other sources: sediment resuspension, atmospheric deposition
- The need to have a better understanding of the Bay's resources
- Currently scheduled TMDLs: coliform FY01/02; metals FY03/04; chlordane FY05/06

Malibu Creek Watershed
- Excessive freshwater, nutrients, and coliform in lagoon; contributions from POTW and other sources
- Urban runoff from upper watershed
- Impacts to swimmers/surfers from lagoon water
- Septic tanks in lower watershed
- Appropriate restoration and management of lagoon
- Access to creek and lagoon by endangered fish
- Currently scheduled TMDLs: nutrients and coliform FY01/02

Ballona Creek Watershed
- Trash loading from creek
- Wetlands restoration
- Sediment contamination by heavy metals from creek to Marina del Rey Harbor and offshore)
- Toxicity of both dry weather and storm runoff in creek
- High bacterial indicators at mouth of creek
- Currently scheduled TMDLs: trash FY00/01, coliform FY02/03PCBs and pesticides FY03/04 and 04/05, metals FY03/04 and 04/05

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7) Los Angeles River Watershed

- Six major NPDES dischargers (four POTWs)
- 30 minor permits
- 109 dischargers covered by general permits
- Industrial storm water – 1,327 dischargers
- Construction storm water - 147 dischargers
- Nitrogen and coliform contributions from septic systems
- Other nonpoint sources (horse stables, golf courses)
- Cross-contamination between surface and groundwater
- Protection and enhancement of fish and wildlife habitat and recreational areas
- Removal of exotic vegetation
- Balancing removal of vegetation for flood control with the need for urban habitat
- Attaining a balance between water reclamation and minimum flows to support habitat
- Leakage of MTBE from underground storage tanks
- Contaminated sediments within the LA River estuary
- Impairments: nitrogen, trash, selenium, other metals, coliform, PCBs, historic pesticides, chlorpyrifos
- Currently scheduled TMDLs: trash 00/01, nitrogen and coliform FY01/02, metals FY03/04, historic pesticide FY05/06

8) San Gabriel River Watershed

- Eight major NPDES dischargers (five POTWs)
- 23 minor permits
- 65 discharges covered under general permits
- 549 dischargers covered under an industrial storm water permit
- 175 dischargers covered under a construction storm water permit
- Sluicing and disposal of sediments from reservoirs
- Protection of groundwater recharge areas
- Ambient toxicity
- Excessive trash in recreational areas of upper watershed
- Mining/stream modifications
- Extensive stream modification for mining and water reclamation
- Urban and storm water runoff quality
- Nonpoint source loadings from nurseries and horse stables
- Lack of understanding of estuary dynamics (e.g. salinity profile)
- Septic systems
- Impairments: nitrogen and effects, trash, metals, historic pesticides, coliform, chlorides, PCBs
- Currently scheduled TMDLs: trash (completed), nitrogen (river) and coliform FY02/03; metals FY04/05, nitrogen (lakes) FY03/04; PCBs & pest. FY05/06

9) Los Cerritos Channel/Alamitos Bay WMA

- Four minor dischargers
- Loss of wetlands habitat in Los Cerritos area
- Impacts from antifouling paint in marinas
- Urban and storm water runoff impacts on isolated water bodies
- Loss of tidal exchange
- Impairments: ammonia, metals, historic pesticides and effects, PCBs, PAHs
- Currently scheduled TMDLs: coliform, ammonia, metals, PAHs, historic pesticides FY04/05

10) The Channel Islands WMA

- Five islands
- One major discharger, four minor dischargers
- Areas offshore of islands designated as Areas of Special Biological Significance
- High quality marine and rocky intertidal habitat
- Heavy use by marine mammals and endangered species
- No known impairments
- Lack of information on water quality

SUMMARY OF REGIONWIDE ACTIVITIES

There are many activities conducted at the Region which do not apply to a specific watershed; instead they represent ongoing regionwide strategies and policies, or programs which are not directly linked to the rotating watershed cycle. Also, statutory, regulatory, or funding requirements may dictate completion of some activities at odd intervals throughout the five-year watershed cycle (such as increased emphasis on pretreatment inspections). The table below gives examples of watershed versus non-watershed related activities.

Watershed Tasks	*Non-Watershed Tasks*
Renew permits	Issue new permits
	Develop new general permits, reduce backlog, pretreatment
Integrate municipal storm water program	Issue individual industrial and storm water permits
Conduct inspections for watershed permits	Conduct inspections on new permits
Enforcement (in-cycle compliance)	Enforcement (spills, out of cycle compliance)
Implement NPS controls	Develop regional strategies to address NPS problems
TMDL/WLAs	
Develop, coordinate and implement watershed monitoring	Coordinate monitoring on a regional scale
Water Quality Assessments (State of the Watershed Reports, partial updates to 305(b) by watershed)	Biennial 305(b) Reports to USEPA
Develop watershed policies	Develop regional policies
Watershed-specific Basin Plan Updates	Regional Basin Plan Updates, Triennial Reviews (as Currently required)
Data management (input and use by watershed)	Regional Database management (development and
GIS (input of watershed-specific layers and information)	GIS (development and input of regional layers and Maintenance of system)
Watershed-specific outreach/education	General outreach education
Incorporation of CEQA and 401 Decisions into watershed planning (as groups are formed, and as timing permits)	Timely review of CEQA documents, 401 certifications per statutory deadlines

While the Watershed Management Initiative strives to integrate and coordinate the various Regional and State Board programs and address the highest priority funding needs for those programs, there is also need to respond to and accommodate priorities established by the individual Regional and State Boards' members, priorities established prior to the WMI which run on their own timelines, or other new mandates which may affect the way the WMI is implemented in a Region. The following briefly describes our overall approach to implementing a subset of programs (some statewide mandates) and other Board priorities on a regionwide scale.

Core Regulatory – General Permits

There are many dischargers in this Region covered by general permits for discharges to surface water through a letter issued by the Executive Officer. This activity occurs independent of the watershed cycle as the need arises. Many of these are for short-term projects such as dewatering. 40 CFR §122.28 provides for issuance of general permits to regulate a category of point sources if the sources: a) involve the same or substantially similar types of operations, b) discharge the same type of waste, c) require the same type of effluent limitations or operating conditions, d) require similar monitoring, and e) are more appropriately regulated under a general permit rather than individual permits.

Core Regulatory – Storm Water Permits

Storm water activities include those involving the three municipal permits (and Standard Urban Storm Water Mitigation Plans associated with the two urban ones) in the Region, the approximately 2700 facilities regulated under the State's general industrial permit, and the approximately 950 construction sites regulated under the State's general construction permit.

Wetlands Protection and Management – Water Quality Certification

A key wetlands regulatory tool for the Regional Board is the CWA Section 401 Water Quality Certification Program which regulates discharges of dredge and fill materials to waters. The 401 certification program is one of the most effective tools the state has for regulating hydrologic modification projects, especially those which directly impact the region's diminishing acres of wetlands and riparian habitat.

Key program activities should include CEQA documents review/response, pre-construction meetings with applicants, site visits, application processing, follow-up monitoring and inspections, and enforcement. Unfortunately, the program is currently severely underfunded with only application processing being undertaken. **The program is currently funded at 2.1 PYs; the FY 00/01 statewide needs analysis for the 401 certification program indicated a needed augmentation of 13.9 PYs.**

Approximately 150-200 applications are processed each year. Information about projects and the program in general is available on the Regional Board website at http://www.swrcb.ca.gov/~rwqcb4/.

Management of Nonpoint Source Pollution

California's Nonpoint Source (NPS) Pollution Control Program has been in effect since 1988; it has recently been updated (January 2000). A key element of the Program is the "Three-Tiered Approach," through which self-determined implementation is favored, but more stringent regulatory authorities are utilized when necessary to achieve implementation.

Our long-term goal for the NPS program is to improve water quality by implementing the management measures identified in *the California Management Measures for Polluted Runoff Report (CAMMPR)* by 2013.

Major current nonpoint source program priorities are: 1) oversight of workplans for 319(h) and Proposition 13 projects, 2) establishment of regional strategies to address agriculture, marinas, and septic tanks (the latter will be focused on densely populated communities and areas where ground water is a source of drinking water), 3) investigation of loading contributions from agriculture, nurseries, golf course, and horse stables (in aid of TMDL work), and 4) expansion of our public education and outreach. It is anticipated our nonpoint source program implementation will heavily emphasize Tier 1, at least initially. **We see a need for an additional 14.0 PYs to fully implement our priorities.**

Enforcement Strategy

The statewide Water Quality Enforcement Policy adopted by State Board in 1996 is intended to make all enforcement consistent, predictable, and fair throughout the state. The Regional Board adopted a resolution in 1997 which confirmed the Regional Board's desire to carry out enforcement in a manner consistent with State Board's enforcement policy and that Regional Board staff prepare a regional enforcement strategy consistent with State Board's enforcement policy. The statewide enforcement policy is currently in the process of being revised.

The enforcement policy states that the Regional Board staff must bring to the attention of their Regional Board for possible enforcement action, at a minimum, an array of permit violations for a variety of dischargers as well as failure to submit reports or deficient reports, and spills. Our increased efforts have resulted in an improved enforcement record for the region and has contributed to increased compliance in some programs (e.g. industrial stormwater). The quarterly violations report is available to the public as part of the Executive Officer's Report; and is also available on the Board's web page.

Beaches/Coastal Watersheds Activities

Due to the great resource and economic value associated with the beaches and coastal watersheds of this Region, a number of activities occur that are specific to the coastal areas. Among these are a number of monitoring programs as well as a program to manage contaminated sediments. Monitoring programs include: several regional surveys of the Southern California Bight which evaluated a number of constituents to determine the spatial extent and magnitude of ecological disturbances, trend monitoring conducted through the State Mussel Watch and Toxic Substances Monitoring Programs, the recently formed Surface Water Ambient Monitoring Program (SWAMP), and a recently developed inventory of Coastal Ambient Monitoring Programs (CAMP).

Additionally, a Contaminated Sediments Task Force has been established to develop a long-term strategy to manage contaminated sediments found in the ports and marinas of Los Angeles County. This effort was funded by the Karnette bill.

FOR ADDITIONAL INFORMATION

Contact the Regional Board's Watershed Coordinator, Shirley Birosik, at (213) 576-6679 or sbirosik@rb4.swrcb.ca.gov for additional information or consult the Regional Board's website at http://www.swrcb.ca.gov/~rwqcb4.

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Section 1 . INTRODUCTION

THE REGIONAL WATER QUALITY CONTROL BOARD - WHY THE WATERSHED MANAGEMENT APPROACH?

The nine Regional Water Quality Control Boards (Regional Boards) are each semi-autonomous and comprised of up to nine part-time Board Members appointed by the Governor. Regional Board boundaries are primarily based on watersheds. Each Regional Board makes water quality decisions for its region. These decisions include setting water quality standards, issuing waste discharge permits, adopting policies, and taking enforcement actions.

The Los Angeles Region has jurisdiction over all coastal drainages flowing to the Pacific Ocean between Rincon Point (on the coast in western Ventura County) and the eastern Los Angeles County line, as well as the drainages of five coastal islands (Anacapa, San Nicolas, Santa Barbara, Santa Catalina, and San Clemente). The Regional Board's jurisdiction also includes all coastal waters within three miles of the continental and adjacent island coastlines.

The Los Angeles Region is the State's most densely populated and industrialized region. Over 1,000 discharges of wastewater from point sources in this Region are regulated by the Los Angeles Regional Board. Over 700 of these point source discharges are discharged to surface waters, and are regulated under the National Pollutant Discharge Elimination System. Permits issued under this program are referred to as NPDES permits. In addition, the Regional Board prescribes Waste Discharge Requirements (WDRs) for the remaining discharges, which are primarily to ground waters and landfills. Up until recently, NPDES permits and WDRs were assessed on a case-by-case basis as they came up for renewal.

In recent years, watershed issues have become much more complex and the need to respond with more coordinated monitoring as well as development of cost-effective solutions has required us to rethink our "permit by permit" approach and move to a watershed approach. In addition, in light of economic constraints, dischargers of point source wastewaters are requesting more consideration of site-specific objectives. At the same time, environmental interests are requesting cumulative assessments of pollutant loadings to waterbodies and impacts to beneficial uses. This requires acknowledgment of the growing importance of nonpoint sources to watershed pollutant loadings. We also have the added need of conducting TMDLs for most of our Region's waters.

Managing water quality by watershed allows the Los Angeles Regional Board to address these varied demands in a more coordinated and effective manner. As the control of point source pollutants through NPDES permits and WDRs is central to the Los Angeles Regional Board's strategy to protect water quality, we have structured our approach to watershed management around the need to issue NPDES permits by watershed, in a timely and coordinated manner over a five-year cycle. This also allows for the gathering of input and coordination of nonpoint source issues within the same framework.

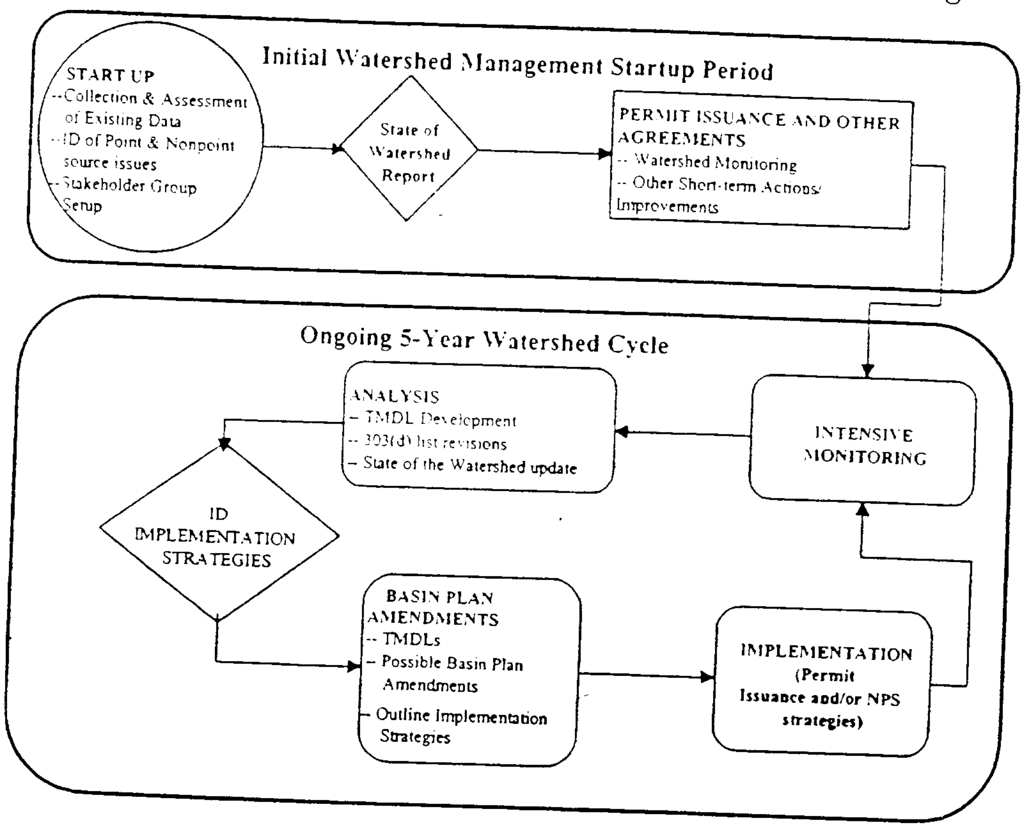
THE WATERSHED MANAGEMENT INITIATIVE

Watershed management is not a new program--it is a strategy for integrating and managing resources. The goal of the state's Watershed Management Initiative (WMI) is to integrate water quality monitoring, assessment, planning, standards, permit writing, nonpoint source management, ground water protection, and other programs at the State and Regional Boards to promote a more coordinated and efficient use of personnel and fiscal resources while ensuring maximum water quality protection benefits. The State's watershed work integrates and supports, to the extent possible, local community watershed protection efforts to implement cost-effective strategies for natural resource protection. As characteristics and resources vary widely from watershed to watershed, this approach customizes efforts to manage resources and address problems unique to each watershed while offering stakeholders the opportunity to implement the most cost-effective solutions to problems within their watersheds.

Watershed management represents a shift from a traditional approach that focuses on regulation of point sources, to a more regional approach that acknowledges environmental impacts from other activities. Over the last twenty-five years, permitting programs have significantly reduced pollutants that are discharged to California's waters from point sources. However, the quality of many waters continues to be degraded from pollutants discharged from diffuse and diverse sources, referred to as nonpoint sources, and from the cumulative impacts of multiple point sources. Future success in reducing pollutants from nonpoint sources and achieving additional cost-effective reductions in pollutants from point sources requires a shift to a more geographically-targeted approach.

Figure 1 illustrates an example of how permitting, planning, and other activities are integrated into our Regional watershed strategy. The upper part of the figure (initial start-up period) refers to work conducted mostly during the first time through the rotating cycle. The lower part of the figure addresses activities that occur during each cycle.

Figure 1. Elements of a Watershed Management Cycle - Region 4



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THE WATERSHED MANAGEMENT INITIATIVE CHAPTER

This document is the fifth iteration of the Chapter. The participants in implementation of the WMI in California (the nine Regional Boards, State Board, and USEPA) were asked in 1996 to begin preparation of a document which identified priorities and resource needs, across programs, in a watershed context. The Chapter is currently used both as an outreach and as a planning tool to identify the Region's priorities over the upcoming two to three fiscal years (FYs), describe where we should spend our baseline resources, as well as where we need additional resources (in support of Budget Change Proposals). It turns out most of our highest priority needs fall into areas that have little to no funding. This effort will hopefully result in flexibility and augmentation to address this deficiency.

The Chapter itself is not a commitment to complete work but provides a framework to identify priorities and resource needs which should form the basis for formal commitments which are made in fund source- and program-specific Workplans on an annual basis. Determinations of which activities will be funded by specific Workplans will be negotiated on the basis of the information in the Chapters. Annual program Workplans and grant applications will still be prepared by program managers to identify which activities are going to be funded in a particular year based on the fiscal decisions made.

The Chapter is organized into sections including the Introduction, Watershed Sections, and Region-wide Section. Included in each Watershed Section is an overview of that watershed, a description of its water quality concerns and issues, past significant Regional Board activities in the watershed, current (funded) activities, near-term (usually unfunded) activities that would benefit the watershed, and activities which may happen on a longer time-scale (usually unfunded). The Region-wide Section includes a description of activities not easily associated with particular watersheds as well as more detailed information on implementation of certain programs (such as nonpoint source) in the Region. The Appendix includes TMDL schedules and lists of permits to be reviewed or renewed each year. More detailed information on allocation of resources may be obtained by request from the Regional Board.

WMI DEFINITIONS

The following represent commonly used terms and definitions utilized throughout the document:

A **watershed** is the geographic area draining into a river system, ocean or other body of water through a single outlet and includes the receiving waters. Watersheds are usually bordered, and separated from other watersheds, by mountain ridges or other naturally elevated areas.

The **watershed management approach** is the specific method by which the Regional Board implements watershed management. Features include the targeting of priority problems, stakeholder involvement, developing integrated solutions, and evaluating measures of success. The entire watershed, including the land mass draining into the receiving water, is considered.

Watershed Management Areas (WMAs) are the geographically-defined watershed areas where the Regional Board will implement the watershed approach. These generally involve a single large watershed within which exists smaller subwatersheds but in some cases may be an area that does not meet the strict hydrologic definition of a watershed e.g. several small Ventura coastal waterbodies in the region are grouped together into one WMA.

State of the Watershed/Water Quality Characterization Reports are reference documents produced by Regional Board staff that describe the existing water quality conditions, data gaps, and sources of pollutants within a WMA. Strategies to resolve the water quality concerns, either in progress or proposed, are described. Preliminary versions of these reports are produced by the Regional Board in order to stimulate discussion and inputs on issues from other stakeholders. These documents will be updated as needed. First edition reports are available for Calleguas Creek, Santa Monica Bay, Los Angeles River, and San Gabriel River Watersheds.

A **Watershed Management Plan** is a planning document often produced by watershed stakeholder groups which addresses water quality, land use, economic, habitat, recreation, and other concerns and recommends specific management strategies to resolve identified problems in a cooperative and coordinated manner. Should stakeholder involvement be lacking, a plan which focuses on water quality concerns will be produced by the Regional Board and would emphasize a more regulatory approach to water quality improvement.

Nonpoint sources of pollution are those with no single point of origin. Pollutants may often be carried off the land by stormwater or be part of urban runoff. Common nonpoint sources are agricultural, urban (runoff from residential areas, parking lots, streets, etc.), and construction activities. **Point sources**, on the other hand, by definition originate from a discrete source such as a pipe or outfall through which a facility may discharge while regulated by a NPDES permit.

Beneficial uses are those uses of water identified in state and regional water quality control plans that must be achieved and maintained. Uses include contact water recreation, municipal water supply, navigation, agricultural supply, wildlife habitat, and groundwater recharge, among others. **Designated** beneficial uses, together with water quality objectives, form water quality standards as mandated under the California Water Code and Federal Clean Water Act. The California Water Code defines **water quality objectives** as "the allowable limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or prevention of nuisance within a specific area." These objectives are both narrative (descriptive) and numerical and appear in each Regional Board's water quality control plan (**Basin Plan**) which also describes implementation programs to protect all waters in the Region.

Best Management Practices (BMPs) are intended to reduce the amount of pollutants and prevent pollutants from leaving a facility and reaching a waterbody. BMPs include good facility housekeeping methods and such things as scheduling certain types of work around periods of rainfall or high winds, controlling runoff from a facility and modifying practices to reduce the possibility of pollutants leaving a facility. These are often used in regulating stormwater and other nonpoint sources.

The **Total Maximum Daily Load (TMDL)** is a number that represents the assimilative capacity of a receiving water to absorb a pollutant. The TMDL is the sum of the individual wasteload allocations for point sources, load allocations for nonpoint sources plus an allotment for natural background loading, and a margin of safety. TMDLs can be expressed in terms of mass per time (the traditional approach) or in other ways such as toxicity or a percentage reduction or other appropriate measure relating to a state water quality objective. A TMDL is implemented by reallocating the total allowable pollution among the different pollutant sources(through the permitting process or other regulatory means) to ensure that the water quality objectives are achieved.

- **TMDLs** establish the loading capacity of a watershed, identify needed reductions, identify sources, and recommend allocations for point and nonpoint sources.
- The **Margin of Safety** is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody.
- **Grouping TMDLs** is a reasonable and logical way to collapse the total number of individual TMDLs to make the most effective use of resources we currently have and any which we may obtain in the future. This is largely due to the fact that some of the "pollutants" for which a water may be listed are actually "effects" of pollutants. The TMDL chart in each watershed section of this report reflects this collapsed approach. For example, many reaches of the Los Angeles River are listed for ammonia. Some of the same reaches are listed for pH problems while other reaches are listed for algae, scum, and odors. It is very likely the presence of these "pollutants" are interrelated. Excessive nitrogen (reflected here as high levels of ammonia) may lead to a condition of eutrophication (excessive nutrient loading) which can influence pH levels as well as promote increased algal growth. Scum may be evident due to floating algal material and odors may result when excessive algae starts to die off. Thus, it makes sense to group these approximately 95 TMDLs (calling it a "nitrogen and related effects" TMDL "group") and approach the problem by determining the sources of nitrogen loading into the watershed and the appropriate allocations in order to reduce loadings.

OVERVIEW OF ONGOING REGIONAL BOARD PROGRAMS AND ACTIVITIES

The Regional Board implements a wide variety of programs with different mandates, requirements, etc. Many of these (most surface water programs) are already fully or partially integrated into the watershed approach; others (primarily ground water) will be incorporated later and a few will likely remain separate from the WMI process. The following gives a brief description of these major program areas, current priority activities for each, and whether they are considered Category One or Two activities. **Category One** activities are those of high priority which are required by federal or state statute or regulation that need to be completed at least once during the 5-year planning cycle. **Category Two** activities are considered very important but are not required by statute or regulation. Additionally, more specific program objectives and implementation activities are included in the watershed or region-wide sections as appropriate. Updated information on Regional Board activities and programs may be also found on the Board's webpage at http://www.swrcb.ca.gov/~rwqcb4.

SURFACE WATER

Core Regulatory (Category One)

Core regulatory activities include NPDES (individual permits - updates and revisions, issuance of general permits, stormwater permits/program, enforcement actions, response to complaints, compliance and pretreatment inspections, pretreatment audits, and review of monitoring reports), groundwater protection activities (issuance of Waste Discharge Requirements), issuance of Water Reclamation Requirements, and land disposal under Chapter 15 California Code of Regulations. Issuance of new permits continues to be a high priority. Reduction of backlog and increased efforts in compliance and enforcement are also very high priorities. Permits are scheduled for reissuance to coincide with targeted watersheds on a rotating schedule of five years. Major NPDES permittees are inspected at least once annually while those in Significant Noncompliance are inspected at least quarterly until the noncompliance issue is resolved. Minor NPDES permittees are inspected at least once in each permit reissuance cycle (20% of the total per year). Those in noncompliance will be inspected annually until the problem is resolved.

Our FY01/02 focus in the core regulatory workplan will be on reducing backlogs, increasing inspections, and increasing our emphasis on pretreatment. Our watershed efforts will focus on coordinating receiving water monitoring and implementing bioassessment. Storm water will put an increased emphasis on compliance inspections and enforcement.

An additional core regulatory task follows adoption of the statewide Consolidated Plan for cleanup of toxic hot spots (in sediment). The Water Code requires reevaluation of those WDRs that may influence the creation of further pollution of known toxic hot spots.

Core regulatory must also implement waste load allocations established by TMDLs during renewal of existing permits or issuance of new permits.

Monitoring and Assessment (Categories One and Two)

Category One activities include the biennial Water Quality Assessment 305(b) Report, Surface Water Ambient Monitoring Program (SWAMP), and Los Angeles Basin Contaminated Sediment Task Force work. Category Two activities include involvement with the State Mussel Watch/Toxic Substances Monitoring Programs (SMW/TSMP), special studies, and volunteer monitoring.

Monitoring and/or assessment efforts are occurring on both regional and watershed scales. The State Mussel Watch and Toxic Substances Monitoring Programs (SMW/TSMP), the recently concluded Bay Protection and Toxic Cleanup Program (BPTCP), Los Angeles Basin Contaminated Sediment Task Force, and Regional Board ambient monitoring through the SWAMP are the major regional monitoring and/or activities with direct coordination provided by Regional Board staff (the SMW/TSMP, BPTCP, SWAMP, and Contaminated Sediment Task Force are described in more detail in the Region-wide Section of this document while activities specific to each watershed are described in the appropriate watershed sections). Also, every two years an update of the 305(b) report is required; emphasis will be put on updating targeted watersheds at those times. It should be noted, however, that an update to 305(b)/303(d) was not required in April 2000. The next scheduled update will be due to USEPA in April 2002.

Monitoring can have a number of goals. It may be used to assess trends over time and obtain general assessment information on a regional scale (ambient monitoring, TSMP, and, to some extent, the SMWP). It may be used to pinpoint "hot spots" and track sources on a watershed scale (BPTCP and ambient monitoring). It may also be used to assess loadings for TMDLs. An increasing use will be to better judge impairments of beneficial uses on a watershed scale and to assess effectiveness of nonpoint source BMPs and other water quality improvement strategies.

A major long-term monitoring and assessment goal is to increase utilization of biological assessments including incorporating them in monitoring requirements for dischargers.

Basin Planning (Categories One and Two)

Category One basin planning activities include conducting triennial reviews of planning priorities, development of water quality standards and implementation plans and policies, development of TMDLs, and preparation of Basin Plan amendments (some of which follow from development of TMDLs).

A triennial review is a fundamental planning function at Regional Boards. This activity provides the Board with the opportunity to review the status of water quality, identify issues and problems, and solicit direction and comment from concerned parties as well as the public in general. The triennial review process sets the stage for possible changes (i.e. amendments) to the Basin Plan, which may be needed to more effectively protect water quality. Amendments to the Basin Plan also ensure that the Regional Board's approach to protecting water quality is legally sound. A triennial review is currently underway.

Another important planning function is interaction with the public and other agencies that are planning projects that may impact the environment. Under the California Environmental Quality Act, the Regional Board has an opportunity and responsibility to work with the public to ensure projects that may affect water quality are properly designed to reasonably mitigate adverse impacts. This responsibility to participate in the planning processes at other agencies extends to the development of regulations (such as the California Toxics Rule and State Implementation Policy) and guidelines (such as irrigation practices). Review of environmental documents is a Category Two activity.

***Wetlands Protection and Management* (Categories One and Two)**

Wetlands acres in the Region have diminished greatly over the past several decades as coastal development, in particular, has increased. Wetlands provide habitat, serve to slow down water flow, decrease total volume through infiltration, and filter out a number of pollutants through active uptake by plants as well as deposition in sediments. Wetlands such as coastal estuaries are a buffer zone between ocean and inland water resources and are heavily utilized by aquatic organisms. Continuous stretches of riparian habitat function as wildlife corridors to allow animal movement between increasingly isolated populations. They also serve as popular recreational destinations for residents and visitors. Unfortunately, many of our Region's wetlands are impacted by varying kinds and amounts of pollutants and alterations.

The Regional Board participates in the Southern California Wetlands Recovery Project, which for the first phase effort, conducted an inventory of coastal wetlands from Santa Barbara to the U.S.-Mexico border. This inventory included information on twelve wetlands in seven watersheds for our region. When compared to estimated historical acreages, Los Angeles County has lost 93% of its wetlands while Ventura County has lost 58% of its wetlands. A 20-year regional wetland plan and strategy for prioritizing and restoring sites is being developed. Currently, the Project funds wetlands projects which involve planning, restoration, or acquisition. More information about the Project may be found on its webpage at http://www.coastalconservancy.ca.gov/scwrp/index.html.

Our wetlands regulatory tools include:

1. **Wetlands beneficial use designation**: The Region's Basin Plan now includes a beneficial use category for Wetland Habitat.

2. **Water Quality Objective:** The Region's Basin Plan has a narrative objective for wetlands protection which addresses the protection of hydrologic conditions and physical habitats to sustain the functional values of regional wetlands.

3. **Water Quality Certification (401) Program**: A key Category One activity associated with wetlands protection and management is CWA Section 401 certification which regulates discharges of dredge and fill materials to waters. The 401 certification program is one of the most effective tools the state has for regulating hydrologic modification projects, especially those which directly impact the region's diminishing acres of wetlands and riparian habitat.

4. **Wetland Grant:** Funding for mitigation monitoring has been requested.

***Nonpoint Source Program** (Categories One and Two)*

Nonpoint source Category One activities include coordination of 319(h) grant project activities, implementation of TMDLs and implementation of Coastal Zone Act Reauthorization Amendments provisions. Participation in stakeholder/watershed groups meetings and activities and public/agency outreach are Category Two activities.

California's Nonpoint Source (NPS) Pollution Control Program has been in effect since 1988. A key element of the Program is the "Three-Tiered Approach," through which self-determined implementation is favored, but more stringent regulatory authorities are utilized when necessary to achieve implementation. The NPS Program has been upgraded to enhance efforts to protect water quality, and to conform with the Clean Water Act Section 319 (CWA 319) and Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA). The lead State agencies for the NPS Program are the SWRCB, the nine RWQCBs, and the California Coastal Commission.

Our long-term goal for the NPS program is to improve water quality by implementing the management measures identified in the California Management Measures for Polluted Runoff Report (CAMMPR) by 2013. The short-term plan to achieve this goal is to identify, educate, and promote stakeholder involvement.

Current nonpoint source program priorities are: 1) oversight of workplans for 319(h) and Proposition 13 projects, 2) establishment of regional strategies addressing agriculture, marinas, and septic tanks (the latter will be focused on densely populated communities and areas where ground water is a source of drinking water), 3) investigation of loading contributions from nurseries, golf course, and horse stables (in aid of TMDL work), and 4) expansion of our public education and outreach. Certain sources (e.g., commercial and multi-family septics) may be regulated with waste discharge requirements.

GROUND WATER

The following programs under our Groundwater Division are currently not managed under our watershed schedule. Over time, we expect to integrate aspects of these programs with other watershed activities, particularly with regard to coordination of monitoring and assessment activities and GIS. Steps taken to date include the mapping of drinking water wells and underground storage tank AND Well Investigation Program (WIP) sites in a Geographic Information System (GIS).

***Underground Storage Tanks Regulation and Remediation** (Category One)*

Responsibilities include oversight of investigations into groundwater pollution and any corrective actions which may be needed which result from leaking underground storage tanks. Cases are roughly organized along watershed boundaries.

***SLIC Program** (Category One)*

Response to reports of unauthorized discharges, such as spills and leaks from above-ground storage tanks which may impact any of the region's waterbodies, are investigated through the

Spills, Leaks, Investigation and Cleanup (SLIC) Program and remediation actions are implemented.

DOD and DOE Sites Cleanup Program *(Category Two)*

The Regional Board works with a number of other agencies involved with remedial investigation and cleanups at U.S. Department of Defense (DOD) and U.S. Department of Energy (DOE) sites. Agreements with the DOD and DOE provide for accelerated cleanups at military bases and other Defense sites schedule for closure.

Well Investigation Program *(Category One).*

Followup investigation of volatile organic compounds in public water supply wells is conducted through the Well Investigation Program (WIP). Investigations focus on identification and elimination of sources of pollutants in public water supply wells, the identification of responsible parties, and oversight of soil and ground water remediation. In a way, this program is watershed-based as it focuses on two watersheds – San Gabriel and San Fernando (upper Los Angeles River).

FUNDING

Many high priority (in terms of Regional Board as well as statutory priorities) activities are unfunded or underfunded. For example, monitoring and assessment, basin planning, and nonpoint source activities are grossly underfunded (we see a shortfall of 14.0 PYs in resources needed to implement our priorities for the NPS program and a statewide needs analysis revealed a 13.9 PYs shortfall in the 401 certification program) . Some resources must be utilized for required activities such as triennial Basin Plan reviews and Water Quality Assessments. The latter activity tells us where our impaired waters are and there are federal requirements to conduct TMDLs on 303(d)-listed waters although more money is needed to do TMDL work on the problem waters (for example, we foresee a shortfall of 8.8 PYs and $650,000 in contract monies for FY00/01 TMDL work). If a TMDL is completed and a remediation strategy developed despite this, there is then little money for followup work, particularly with regards to dealing with nonpoint source contributions. This means that our involvement in nonpoint sources must be very time-conservative. While it may take years of work to cooperatively fix a nonpoint source problem, direct enforcement could take a lot less time and be an immediate action. However, the latter is contrary to the cooperative spirit of watershed management. Each watershed will require difference site-specific approaches depending on a variety of factors. Additionally, enforcement is another underfunded activity, particularly when dealing with nonpoint source discharges. On the other hand, priorities may shift due to the influx of "new" money to fund a previously underfunded, and often times, lower priority activity. Use of the new money may be specific to certain activities such as increased pretreatment inspections in the core regulatory program. See Table 1 for the funding status and priority of Regional Board activities and programs in greater detail.

Table 1. Funding Status of Major Regional Board Activities and Programs

Program/Activity (and Subcategories)	Import-ance (High, Med, Low)	Man-dated?	Current Funding	What We Can Do With Existing Funds	What Could Be Done with More Funds
Basin Planning					
Triennial reviews	M	Y	*Under-funded*	*Absolutely necessary updates; delayed and/or limited Triennial Reviews*	*Conduct regular comprehensive reviews of the Basin Plan and associated issues; act on an increased number of triennial review-listed items*
Evaluation of beneficial uses	H	Y	*Under- to unfunded*	*Field observations in conjunction with other activities*	*Comprehensive beneficial use surveys (necessary to set and refine use designations)*
Development of WQ objectives	H	Y	*Under- to unfunded*	*Utilize existing objectives.*	*Develop new and/or site-specific objectives; participate on State/Federal Task Forces; develop regional policies to implement water quality standards*
Development of watershed/ regional priorities	H	N	*Under-funded*	*Solve the easiest problems*	*Develop of complex watershed solutions*
Watershed Coordination and Plan Development	H	N			
Development of watershed plans	H	N	*Under to unfunded*	*Rely on stakeholders to do most of the work*	*Ability to provide staffing efforts to watershed groups to guide and prepare integrated plans for water quality along with flood protection, habitat protection, etc.*
Coordination	H	N	*Under-funded*	*Limited outreach*	*Provide staff to participate in all watershed groups*
TMDL Development	H	Y	*Under-funded*	*TMDLs with only the required elements in order to meet deadlines*	*More time spent developing TMDLs with site-specific information*

Program/Activity (and Subcategories)	Import-ance (High, Med, Low)	Man-dated?	Current Funding	What We Can Do With Existing Funds	What Could Be Done with More Funds
Water Quality Assessment					
Monitoring — Ambient watershed	H	Y (SWAMP)	*Under-funded*	*Do the basics required by the SWAMP; minimal staff sampling; rely on stakeholder sampling with minimal oversight; develop collaborative discharger watershed monitoring programs*	*Collect better data to assess impacts, assess for more constituents with more robust sampling; develop priorities, and evaluate successes; actively solicit and coordinate stakeholder monitoring; move beyond "snapshot" monitoring*
Lab support	H	N/A	*Under-funded*	*Evaluate small subset of waters; analyze inexpensive constituents; often inadequate for decision-making*	*Utilizing "better science" for decision-making*
Biomonitoring (training /field wk.)	H	N	*Under-funded*	*Use effluent chronic toxicity testing as surrogate*	*Real assessment of impacts to Beneficial Uses through field surveys*
Assessment	H	Y (WQA)	*Unfunded*	*Compile and assess as time permits ("back-burner")*	*Utilization as a critical element in watershed decision-making*
Computer data storage	H	N	*Unfunded*	*Data stored in many locations*	*More efficient and comprehensive analyses*
Analyze data	H	Y	*Unfunded*	*Simple statistics*	*More rigorous analyses*
State of watershed report	M	N	*Unfunded*	*Summarize available info*	*Info sharing/priority setting*
Biennial WQA Report	M	Y	*Unfunded*	*Limited to targeted watersheds (minimal info)*	*Regular and more comprehensive updates/ better data for quality decisions*
Reporting – *Water Quality Report Card*	H	N	*Unfunded*	*Encourage other groups to develop indicators that would be useful for our Region*	*Research and develop indicators and a "report card" format for Region*

Program/Activity (and Subcategories)	Importance (High, Med, Low)	Mandated?	Current Funding	What We Can Do With Existing Funds	What Could Be Done with More Funds
CEQA Review	M-H	Y	*Unfunded*	*Limited to highest priority projects with the greatest potential impacts*	*Provide early, meaningful comments; pre-401 coord.; early notification; be aware of piecemealing of projects*
401 Review	M-H	Y	*Under-funded*	*Review and process applications*	*Follow-up work (monitoring and enforcement), pre-construction meetings, site visits, review of draft CEQA documents, development of regional policies*
Nonpoint Source/CZARA					
Outreach	H	N	*Under-funded*	*Minimal effort - usually associated with group meetings*	*More active cooperation and outreach with individuals and groups in the watershed*
Contract/Project Management	H	N	*Under-funded*	*Minimum needed to get project through funding process*	*Receive better products and leverage from successful projects, hands on involvement and advertisement of successful projects*
Development of NPS Solutions	H	Y	*Under-funded*	*Little to none on our own; some involvement with others' work, and initiation of regulatory mechanisms (Tiers II and III)*	*Work with watershed communities to develop and implement nonpoint pollution control strategies, evaluate success of best management practices and management measures*
Permitting - Point Source (NPDES and WDRs)					
Permit development	H	Y	*Under-funded*	*Reduce backlog; process major and minor permits on watershed schedule/transfer minor permits to general permits as time allows*	*Have resources to solicit more stakeholder involvement; use higher level tools (modeling) to develop limits*
Inspections	H	Y	*Under-funded*	*Minimum required*	*More field presence/outreach/may reduce need for enforcement*
Enforcement	H	Y	*Under-funded*	*Only high profile major spills/violations*	*More enforcement actions taken on spills/violations that are not high profile*
Spill/complaint follow-up	H	Y/N	*Under-funded*	*Only major spills*	*Better customer service, follow-up on complaints, successful cleanups*

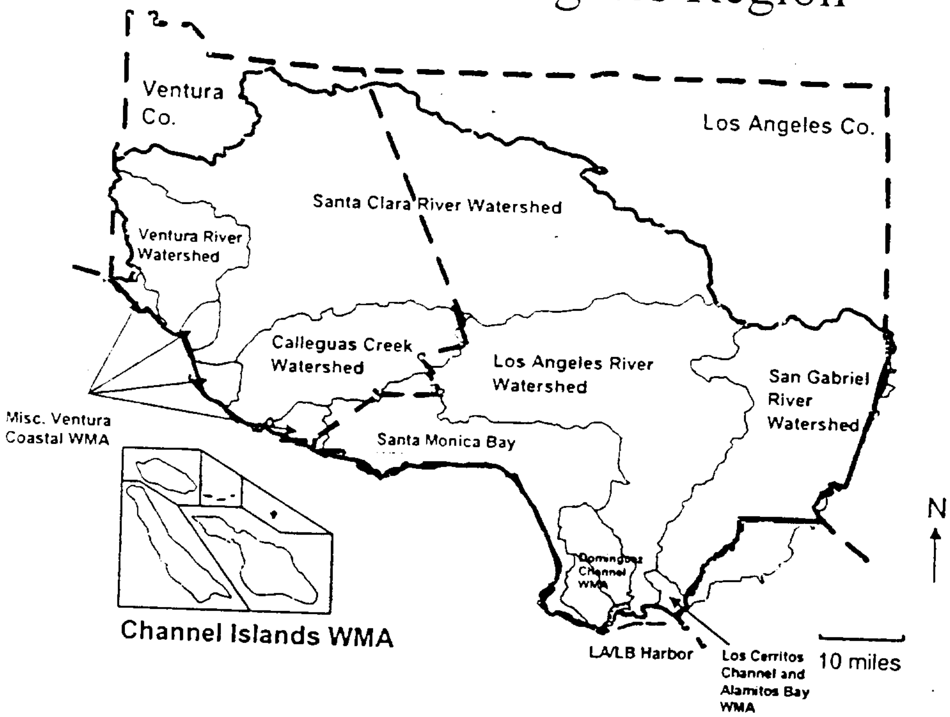
OUR REGION'S APPROACH TO WATERSHED MANAGEMENT

We have designated ten watershed management areas in the Los Angeles Region (Figure 2). Initially, implementation of watershed management in the Los Angeles Region occurred in phases over a seven-year cycle for each watershed. We are now shifting to a five-year cycle to be in line with the standard permit life and to equalize workloads over the years. This shift in our watershed cycle is illustrated in the table that follows. The majority of permit-related tasks such as permit renewals/revisions and regional monitoring program development as well as preparation of state of watershed reports, will occur during the first approximately twelve months of the watershed's five-year cycle. Much of the rest of the cycle will be spent developing and implementing, with the input of stakeholders, measures for management of pollutants from point and/or nonpoint sources. In some cases, nonpoint source activities may be occurring throughout the cycle due to the prior existence of stakeholder groups who have been meeting regularly on these issues. Toward the end of the five-year cycle (and prior to initiating the next cycle), we shall evaluate the success of our watershed efforts.

In light of limited schedules and resources, efforts during the 12-month start-up phase will target compilation and assessment of available data, identification of data gaps and the need for additional studies/monitoring, the development of a balanced stakeholder group, and issuance of permits for point source discharges. A by-product of these efforts will be a preliminary indication of pollutant problems from nonpoint sources; followup efforts to address these nonpoint source problems, as well as other water quality problems, will be undertaken during the cycle if efforts are not already underway through some other means.

NPDES permits in the Los Angeles Region are organized and scheduled by watershed. Preliminary "State of the Watershed Reports" are prepared by watershed "teams" composed of permit writers, planning and nonpoint source program personnel, and those involved with groundwater protection. These reports have become very useful tools for local watershed groups for general educational value and in setting priorities.

Figure 2. Watershed Management Areas of the Los Angeles Region



Permit Timeline for Watershed Management Initiative

Santa Clara River Calleguas Creek	FY 2001/02
Dominguez Channel-LA/LB Harbor	FY 2002/03
Santa Monica Bay	FY 2003/04
Los Angeles River	FY 2004/05
San Gabriel River Los Cerritos Channel Channel Islands	FY 2005/06
Ventura River Misc. Ventura Coastal Santa Clara River Calleguas Creek	FY 2006/07
Dominguez Channel-LA/LB Harbor	FY 2007/08

The formation of a balanced group of stakeholders for each watershed is critical to the success of watershed management, especially for resolving issues arising from nonpoint source pollutants. Accordingly, part of our approach is to initiate such groups of stakeholders and encourage active participation. Working in partnership with stakeholders, we expect that we can achieve the following goals (or have already done so during the watershed's first cycle) within each of our watershed management areas during the first five-year cycle of watershed management.

- **Establishment of a stakeholder group** or an infrastructure of stakeholder contacts which represents a range of key interest groups in the watershed; yet involvement is not a barrier to timely resolution of a water quality problem.
- **Compilation of reasonably available water quality data** and related information in the form of a 'State of the Watershed Report.'
- **Assessment of data gaps** and a plan to fill the gaps.
- **Development of a** coordinated, cost-effective **watershed-wide monitoring program.**
- **Identification of priority permit issues** and **coordinated issuance of NPDES permits** that addresses these issues.
- **Identification of other high priority issues**, including nonpoint source issues, and consensus among stakeholders as to how to proceed to resolve them.
- **Implementation of watershed-based solutions.**
- **Evaluate** success.

Many of the tasks noted above will not be limited to a particular part of the watershed cycle. Rather, some may overlap throughout the watershed cycle as may be the case with tasks such as review and assessment of monitoring data and permit compliance. Also, some tasks may have less emphasis than others depending on the watershed, its problems, and the relative influence of point versus nonpoint source contributors.

What is important is the basic tenets of watershed management are being implemented:

- *The effort has a geographic focus,*
- *The highest priority issues are being identified and addressed,*
- *Stakeholder involvement is occurring, and*
- *A scientific basis for water quality management decisions is being created.*

While this is an idealized model, many factors often change what can be done for each step. these include regulatory or statutory mandates, consent decrees, legislation, and changes in Board priorities or funding.

OUR HIGH PRIORITY ISSUES UNDER THE WMI

This Regional Board establishes priorities on an annual basis. While some of these priorities fall outside of the watershed management arena (it is acknowledged that some activities will likely always remain outside of the WMI), the bulk of these priorities are clearly of primary importance in fulfilling not only the WMI but also the nonpoint source management initiative and other mandates. For example, one major priority is, in fact, implementation of the watershed approach. In addition to Regional Board-directed priorities, priorities are mandated by legislation, statute, regulation, State Board, Cal-EPA, USEPA, and from sheer need to protect, restore, or enhance water quality. A list of the highest of these collective priorities follows. These are not necessarily arranged in priority order.

- **Point sources** – controlling compounds which continue to cause instream toxicity and/or accumulate in sediments or biota.
- **Industrial discharges** – ensuring compliance with either individual or general permits.
- **New/re-development** – proactively addressing water quality issues through CEQA, 401 certifications, or stormwater permits – ensuring wet weather compliance with construction permits.
- Addressing the **regional salt management**/salt imbalance issue which is becoming increasingly critical in the region. Also, balancing this issue with the need to promote the use of reclaimed water.
- **Municipal stormwater/urban runoff** – advancing stormwater and urban runoff programs through a variety of efforts. Current priorities include trash control and new development/re-development issues.
- **Watershed monitoring and assessment** – coordination of existing resources and participation in the Surface Water Ambient Monitoring Program. More use of bioassessment as a tool.
- **Water quality standards** program – although this is the cornerstone of all of our programs, it has been minimally funded for the last two decades. This is a critical need for our organization to address this deficiency.
- **Habitat loss/restoration** – even with strides in improving instream water quality, unless habitat is restored, in many cases beneficial uses can not be restored. Efforts which address this need are 401 certification, the Southern California Wetlands Recovery Project, and various watershed efforts. Removal of exotic species is also included in these efforts.
- Priority **nonpoint source** efforts – several areas have been targeted for accelerated efforts including development of regional strategies to address agriculture, septic tanks, urban runoff, and marinas as contributors of nonpoint source pollution as well as involvement with grant funding activities relating to CWA Section 319(h) and Proposition 13.
- **Toxic hot spots** (sediment) – many of the impairments in the Region, particularly in harbors, are related to contaminated sediments. While source reduction will decrease pollutant levels over time, remediation of these sediments will also be needed which will be a long-term project. An effort to help address this need is the Contaminated Sediments Task Force.
- **Beach closures** – other impairments in the Region are the result of elevated coliform levels or beach closures. Monitoring the water quality of recreational areas along the coast, identifying land uses or drainages which generate pathogens, and reducing pollution within these areas is a targeted activity.

These Board priorities are further highlighted in the watershed and region-wide sections as appropriate.

Section 2 . Activities Organized on a Watershed Basis

This section describes activities organized on a watershed basis. An **overview** of each watershed or WMA is provided, its **water quality problems and issues** are described, **past significant activities** (as appropriate), **current activities** (funded activities, in FY00/01 workplan), **near-term activities** (planned or projected high priority activities that may need funding, especially beginning in FY01/02), and **potential long-term activities** (long-term goals, beyond two years).

A table has been included in the Region-wide Section which describes non-TMDL-related resource needs for FY01/02. TMDL resource needs are also included in the Region-wide Section of this document.

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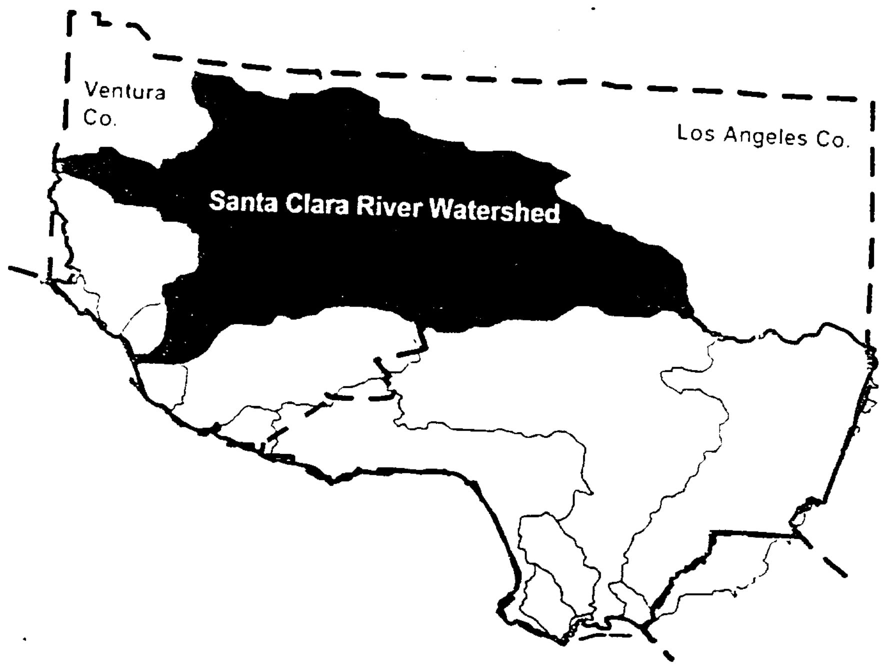
2.1 *SANTA CLARA RIVER WATERSHED*

This watershed will be targeted for permitting purposes in FY01/02.

Overview of Watershed

Size of watershed: approximately 1,200 sq. mi.

Length of river: approximately 100 miles



The Santa Clara River is the largest river system in southern California that remains in a relatively natural state; this is a high quality natural resource for much of its length. The river originates in the northern slope of the San Gabriel Mountains in Los Angeles County, traverses Ventura County, and flows into the Pacific Ocean halfway between the cities of San Buenaventura and Oxnard.

Extensive patches of high quality riparian habitat are present along the length of the river and its tributaries. The endangered fish, the unarmored stickleback, is resident in the river. One of the largest of the Santa Clara River's tributaries, Sespe Creek, is designated a wild trout stream by the state of California and supports significant spawning and rearing habitat. The Sespe Creek is also designated a wild and scenic river. Piru and Santa Paula Creeks, which are tributaries to the Santa Clara River, also support good habitats for steelhead. In addition, the river serves as an important wildlife corridor. A lagoon exists at the mouth of the river and supports a large variety of wildlife.

Water Quality Problems and Issues

Increasing loads of nitrogen and salts in supplies of ground water threaten beneficial uses including irrigation and drinking water. Other threats to water quality include increasing development in floodplain areas which has necessitated flood control measures such as channelization that results in increased runoff volumes and velocities, erosion, and loss of habitat. In many of these highly disturbed areas the exotic giant reed (*Arundo donax*) is gaining a foothold.

Beneficial Uses in watershed:

Estuary	*Above Estuary*
Contact & noncontact water recreation	Contact & noncontact water recreation
Wildlife habitat	Wildlife habitat
Preservation of rare & endangered species	Preservation of rare & endangered species
Migratory habitat	Migratory habitat
Wetlands habitat	Wetlands habitat
Spawning habitat	Municipal supply
Estuarine habitat	Industrial service supply
Marine habitat	Industrial process supply
Navigation	Agricultural supply
Commercial & sportfishing	Groundwater recharge
	Freshwater replenishment
	Warmwater habitat
	Coldwater habitat

Permitted discharges:

- Four POTWs (one discharge in estuary, one in middle reaches, two in upper watershed)
- 103 dischargers covered under an industrial storm water permit
- 310 dischargers covered under a construction storm water permit

Many of the smaller communities in this watershed remain unsewered. In particular, in the Agua Dulce area of the upper watershed, impacts on drinking water wells from septic tanks is a major concern. The community is undertaking a wellhead protection effort, with oversight by Board staff. Development pressure, particularly in the upper watershed, threatens habitat and the water quality of the river. The effects of septic system use in the Oxnard Forebay area is also of concern.

Types of permitted wastes discharged into the Santa Clara River Watershed:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	2 1	Minor General
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	6 8	Minor General
Nonhazardous (designated) noncontact cooling water	2	Minor
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	2	Minor
Nonhazardous (designated) stormwater runoff	1	Minor
Hazardous contaminated groundwater	1 1	Minor General
Nonhazardous (designated) filter backwash brine waters	1	Minor
Nonhazardous (designated) domestic sewage & industrial waste	4 1	Major Minor
Nonhazardous (designated) washwater waste (photo reuse washwater, vegetable washwater)	1	General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	12	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations

Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

Twenty-nine of the 43 NPDES discharges discharge into the mainstem of the Santa Clara River while the rest go to various tributaries.

Of the 130 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Motor Freight Transportation and Warehousing*, and *Motor Vehicle Parts, Used* categories.

There are currently 310 sites enrolled under the construction storm water permit with a similar number of sites located in the upper and lower watershed. The majority of these are residential sites 10 acres or larger in size.

IMPAIRMENTS: Limited data (beyond mineral quality and nitrogen) is available for much of the Santa Clara River. The Santa Clara River Estuary and Beach is on the 1998 303(d) list for coliform while a portion of the river upstream of the estuary is listed for ammonia and coliform. Portions of the river have chloride exceedances. The Estuary is also listed for DDT in fish tissue. Two small lakes in the watershed are also on the 1998 303(d) list for eutrophication, trash, DO, and pH problems. Two major spills of crude oil into the river have occurred in the last six years although recovery has been helped somewhat by winter flooding events. Natural oil seeps discharge significant amounts of oil into Santá Paula Creek.

The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
chloride	Basin Plan numeric objective: 80 - 100 mg/l	10 - 138 mg/l (mean of 105 ± 21)	Santa Clara River Reach 9 (Bouquet Cyn Rd to abv Lang Gaging) Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge) Santa Clara River Reach 7 (Blue Cut to West Pier Hwy 99) Santa Clara River Reach 3 (Dam to abv SP Crk./blw Timber Cyn)

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3 - 28.0 mg/l to protect against acute toxicity	ND - 4.9 mg/l (mean of 1.4 ± 1.3)	Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge) Santa Clara River Reach 7 (Blue Cut to West Pier Hwy 99) Santa Clara River Reach 3 (Dam to abv SP Crk /blw Timber Cyn)
nitrate + nitrite	Basin Plan numeric objective: no greater than 10 mg/l	0.3 - 15.4 mg/l (mean of 5.7 ± 2.4)	Wheeler Canyon/Todd Barranca Torrey Canyon Creek Brown Barranca/Long Canyon Mint Canyon Creek Reach 1 Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge)
org. enrichment/ low DO	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	0.8 - 11.0 mg/l (mean of 7.7 ± 2.5)	Santa Clara River Reach 9 (Bouquet Cyn Rd to abv Lang Gaging) Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge) Elizabeth Lake
pH	Basin Plan numeric objective: 6.5 - 8.5 pH units	7.3 - 9.6 pH units (mean of 8.5 ± 0.7)	Elizabeth Lake
odors	Basin Plan narrative objective		Lake Hughes
coliform	Basin Plan numeric objective: Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	20 - 24000 MPN/100ml	Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge) Santa Clara River Estuary
sulfate	Basin Plan numeric objective: 150 mg/l		Santa Clara River Reach 9 (Bouquet Cyn Rd. to abv Lang Gaging)
Eutrophication	Basin Plan narrative objective		Elizabeth Lake Lake Hughes Munz Lake
algae	Basin Plan narrative objective		Lake Hughes
fish kills	Basin Plan narrative objective		Lake Hughes
trash	Basin Plan narrative objective		Elizabeth Lake Munz Lake Lake Hughes
ChemA*	National Academy of Science Guideline (tissue): 100 ng/g		Santa Clara River Estuary
toxaphene	State Board numeric objective (tissue): Max. Tissue Residue Level 8.8 ng/g		Santa Clara River Estuary

* ChemA refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
chloride	Santa Clara River Reaches 3, 7, and 8	01/02
nitrogen	Santa Clara River Reaches 3, 7, and 8 Wheeler Canyon/Todd Barranca Torrey Canyon Creek Brown Barranca/Long Canyon Mint Canyon Creek Reach 1	02/03
eutrophication	Elizabeth Lake Munz Lake Lake Hughes	04/05
trash	Elizabeth Lake Munz Lake Lake Hughes	04/05
coliform	Santa Clara River Reaches 8 and 9 Santa Clara River Estuary Santa Clara River Estuary Beach/Surfers Knoll	05/06

We see a need for an additional 2.2 PYs as well as $100,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Stakeholder Groups

Santa Clara River Enhancement and Management Plan Steering Committee The 26-member Project Steering Committee is currently directing preparation of an Enhancement and Management Plan. The Committee consists of representatives of the following individuals and agencies:

Acton Town Council * Aggregate Producers Agriculture/Private Land Ownership Beach Erosion Authority for Operations & Nourishment * Castaic Lake Water Agency Cities of Fillmore/Santa Paula * City of Oxnard City of San Buenaventura * City of Santa Clarita * County of Ventura - Resource Management Agency * Friends of the Santa Clara River * (environmental organization umbrella group) Los Angeles County Flood Control District * Los Angeles County Sanitation District	Los Angeles Department of Regional Planning - APIS Newhall Land & Farming Company Santa Clara Valley Property Owners Association State of California Coastal Conservancy * State of California Department of Fish and Game * State of California Department of Parks and Recreation * State of California Department of Transportation * - District 7 State of California Water Quality Control Board - L.A. Region * United Water Conservation District U.S. Army Corps of Engineers * U.S. Fish & Wildlife Service * Valley Advisory Committee Ventura County Flood Control District *

* Additionally indicated support for the river study by signing a Memorandum of Cooperation

Six subcommittees worked with a consultant to collect the information necessary for a river management plan: agriculture, flood control, water resources, aggregate industry, recreation, and biology were the areas focused on. These subcommittees worked on determining river dynamics and areas where the interests of diverse groups overlap along the river; the critical issues areas were identified. Reports were developed by the subcommittees that provide background information, goals, and recommendations for the river on the issue areas. A series of computer-based maps have been produced, which are currently being used in a GIS overlay process to identify conflicts and opportunities and facilitate decisions regarding use of the river floodplain. The stakeholder are currently looking for a consultant to put together a CEQA document for a watershed plan.

Friends of the Santa Clara River This non-profit stakeholder group has been involved with watershed activities along the length of the river with a focus on the protection, enhancement, and management of the river's resources. More information about this group may be found at their website http://www.FSCR.org.

Santa Clarita Organization for Planning the Environment (SCOPE) This group has been involved with educating the public about planning and environmental issues, including those involving the river, particularly in the area around the Santa Clarita Valley. More information about this group may be found at their website http://www.scope.org/.

Significant Past Activities

Santa Clara River Enhancement and Management Plan development evolved as the result of the efforts of former Ventura County Supervisor Maggie Kildee, representatives of the Ventura Office of the U.S. Fish and Wildlife Service, and grant funding provided by the State Coastal Conservancy. As far back as 1991, it was becoming apparent that the many proposed and conflicting uses of the river were heading for problems of rather large proportions unless the agencies that regulated the river and the various stakeholders along the river agreed on a consensus plan to manage the river and its resources. The increasingly complex regulatory process along the river, involving protection of river ecology and natural processes, was becoming a more difficult environment for stakeholders wishing to stabilize banks, develop urban projects, or mine river aggregate deposits. The river is a very complex natural system and agencies had been forced to be very conservative in analysis of projects because of incomplete understanding of the river's ecological processes. Large instream aggregate mining projects which had been proposed, plus several urban development projects in the making, led to the feeling that a giant "train wreck" was in store for the Santa Clara River. The options were to keep doing business-as-usual approaches, or to work together to develop a coordinated conservation plan for the river. Therefore, in 1991, Supervisor Kildee invited all concerned parties to participate in initiating the Plan. A Project Steering Committee was formed. Since that time, funding for consulting services associated with Plan development, totaling $510,000 to date, has been provided by the Coastal Conservancy, the State Wildlife Conservation Board, the U.S. Fish and Wildlife Service, the Cities of Santa Clarita and San Buenaventura, and both Ventura and Los Angeles County Flood Control Districts. In addition, a great deal of staff time and in-kind services have been contributed to this planning effort. This project also formed the primary basis for nomination of the Santa Clara River as an American Heritage River. Although the river is still under consideration, it has not yet been designated.

The Steering Committee began by identifying the river's critical issue areas. Reports were developed by subcommittees that provide background information, goals and recommendations for the river on the issue areas. A series of computer-based maps have been produced, which are currently being used in a Geographic Information Systems (GIS) overlay process to identify conflicts and opportunities and facilitate decisions regarding use of the river floodplain.

The Steering Committee initially identified nine main categories of critical resource issue areas and, over the past two years, subcommittees covering Biological Resources, Recreation, Water Resources, and Aggregate Mining have each developed reports providing background information, and goals and recommendations for their respective areas. In addition, two reports covering the History of the Santa Clara River and the Cultural Resources of the River have been published.

One downside to this effort is that the study and plan were limited to the mainstem of the river, not the tributaries or other watershed areas outside of the 100-year floodplain. If additional resources can be found, the study area can be expanded throughout the watershed. This will increase the chance of successful protection of this watershed.

Other important community-based efforts include Ventura County's Agriculture Policy Working Group's Agricultural Land Preservation Program, the Heritage Valley Tourism Development Program, Santa Clara River Valley Historic/Cultural Preservation Programs and the City of Santa Clarita's River Corridor Plan.

In 1990, the Regional Board adopted Resolution No. 90-004 (**Drought Policy**) which had a term of three years and provided interim relief to dischargers who experienced difficulty meeting chloride objectives because of a state-wide drought. The policy adjusted effluent limits to the lesser of 1) 250 mg/l or 2) the chloride concentration in the water supply plus 85 mg/l. In 1995, the Regional Board extended the interim limits for three years and directed staff to develop a long-term solution to deal with the impact of changing water supply, especially during droughts. In 1997, the Regional Board adopted Resolution No. 97-002 (**Chloride Policy**) which set the chloride objective at 190 mg/l except in the Calleguas Creek and Santa Clara River Watersheds where, due to the great concern for protection of agriculture, staff were directed to determine the chloride concentrations sufficient to protect agricultural beneficial uses.

Current Activities

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits and issuance of new permits. This will be a targeted watershed for the bulk of permit renewal purposes in FY 2001-02. There are four major dischargers, 16 significant or minor dischargers under individual permits, as well as 23 dischargers currently covered under general permits (additional information on permits may be found in the Appendix). Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue.

The one POTW discharging to the estuary conducted a limited-term receiving monitoring program to investigate whether toxic constituents (to be regulated under the CA Toxics Rule) are accumulating or bioaccumulating in the estuary.

We anticipate that NPDES permit renewals will focus on 1) compliance with the CA Toxics Rule, 2) nutrients, 3) coordinated monitoring, and 4) biomonitoring.

Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Ventura County Municipal Storm Water Permit (adopted in 2000). The "Discharger" consists of the co-permittees Ventura County Flood Control District, the County of Ventura, and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks. The Discharger is required to implement the approved Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) by January 27, 2001. The SQUIMP shall address conditions and requirements for new development and significant redevelopment.

To date, the storm water monitoring program has consisted of land-use based monitoring combined with receiving water monitoring and modeling. The Discharger intends to sign an agreement to participate in the Regional Monitoring Program established for Southern California municipal programs under the guidance of the Southern California Coastal Water Research Project.

The Santa Clara River receives municipal storm drain discharges from the City of Fillmore, City of Oxnard (part), City of San Buenaventura (part), City of Santa Paula, and unincorporated Ventura County (part).

MONITORING AND ASSESSMENT

The Santa Clara River will be a focus for SWAMP monitoring as the watershed comes up for targeting in the rotating watershed cycle. Currently, we plan on emphasizing stratified random sampling with the strata represented by stretches of river or tributary immediately upstream of confluences. Biological assessment work will be a major component of the program.

The upper Santa Clara River is monitored by the County Sanitation Districts of Los Angeles County under NPDES permits for the Saugus and Valencia treatment plants. Somewhat downstream, between the towns of Piru and Saticoy, water quality in the surface and groundwater is monitored by United Water Conservation District. Mid-river receiving water data is provided by the City of Santa Paula treatment plant under an NPDES permit and occasionally by the City of Fillmore when they discharge to surface waters under an NPDES permit. Otherwise, the City of Fillmore provides groundwater data that has not yet been integrated into the watershed picture. At the river's terminus, some water quality data is available from the City of San Buenaventura under NPDES permit for discharge to ponds adjacent to the river. The monitoring supports compliance evaluation; it is not part of a program for nonpoint source identification or TMDL development. In conjunction with the receiving water monitoring, land-use based monitoring is carried out as part of the Ventura County Municipal Storm Water Program. There is a long stretch of the middle river (surrounded by private property) that has had little to no monitoring because of limited access. Additionally, the Regional Board monitored a number of locations in the river and its tributaries until fairly recently when funding levels were reduced. The Regional Board has conducted some monitoring in the watershed also.

In support of upcoming TMDLs scheduled for the watershed, approximately one dozen sites will sampled along the length of the river this fiscal year for pesticides, nutrients, and minerals.

In addition, efforts to study impacts of chloride on groundwater supplies will require ongoing monitoring. A MOU has been prepared by staff and has been signed by several key stakeholders interested in this issue.

Ground water data are being collected by a number of agencies and should be compiled by the Fox Canyon Groundwater Management Agency. We should be acquiring some of this data over the next two years for use in our analysis of the Oxnard Plain nonpoint source contamination problems.

WETLANDS PROTECTION AND MANAGEMENT

Acquisition of parcels at the mouth of the river (wetlands, dunes and former riparian areas at the estuary as well as at the adjoining McGrath Lake and dunes) is a high priority for FY00/01 and future years funding by the Southern California Wetlands Recovery Project.

The Santa Monica Mountains Conservancy is a state agency created by the Legislature in 1979 charged with primary responsibility for acquiring property with statewide and regional significance, and making those properties accessible to the general public. The Conservancy manages parkland in the Santa Monica Mountains, Santa Susana Mountains, the Simi Hills, the Santa Clarita Woodlands, the Whittier-Puente Hills, the Sierra Pelona, the Los Angeles River Greenway, the Rio Hondo, the Verdugo Mountains, the San Gabriel Mountains, and the San Rafael Hills. The agency's goals are to: 1) implement the Santa Monica Mountains Comprehensive Plan, 2) implement the Rim of the Valley Trails Corridor Master Plan, 3) implement the Los Angeles County River Master Plan, 4) further cooperation with local governments in the region to secure open space and parkland, and 5) expand education, public access, and resource stewardship components in a manner that best serves the public, protects habitat, and provides recreational opportunities.

NONPOINT SOURCE PROGRAM

Santa Clara River Enhancement and Management Plan

A set of computer-based GIS maps has been developed to allow generation of a set of comparative overlay maps demonstrating the potential conflicting uses and compatible opportunities on each of 13 river reaches defined in the Plan.

Using the maps, extensive discussion of issues along the river will take place during a series of Project Steering Committee working sessions. Overlay layers are developed around the resource areas of water resources, flood protection, agricultural resources, aggregate resources, biological resources, cultural resources, recreation, and land use. Within each resource area, individual layers are being developed depicting selected parameters for comparison. For example, for biological resources, layers have been generated showing the various types of riparian vegetation, exotic species, and habitat values. The overlay analysis resulted in identification of the areas of greatest potential conflicts facing the river, and recommendations for addressing these issues, including (1) preserving and maintaining water conveyance and groundwater recharge functions of the river, (2) creating mitigation banks, enhancing significant biological areas, and providing public access opportunities, (3) enhancing populations of threatened and endangered species on the river, with the goal of creating viable and sustainable populations, (4) enhancement and preservation of agricultural land, (5) mitigation of beach erosion issues, (6) implementation of flood protection and bank stabilization facilities, and (7) identification of areas appropriate for development and for sand and gravel extraction.

Following completion in 1998 of the overlay analysis, a Draft Plan with reach-by-reach analyses was developed and public meetings held to discuss the Plan and its ramifications. Environmental review of the Draft Plan will also be carried out prior to developing the Final Plan.

Two demonstration projects under consideration for funding by the Coastal Conservancy would utilize a GIS overlay process for 1) a bank stabilization project using bio-technical methods to promote reduced bank erosion while increasing wildlife habitat, and 2) creation of a mitigation bank on a unique portion of river terrace riparian habitat for the protection and enhancement of wildlife habitat

In April 1999, the Project Steering Committee released preliminary river-wide and reach-specific recommendations for public comment. River-wide recommendations include those involving issues such as public outreach, private property rights, water quality, water rights, saltwater intrusion, water supply, river gradient, public flood protection facilities, maintenance of design flow capacity, private flood protection, cultural resource protection, fish passage, habitat conservation priorities, biological management, control of exotics, biological mitigation, public access and recreation, recreational property acquisition, and permit streamlining.

The group has also developed draft resource-based ranking criteria for parcel acquisition. There is one such parcel acquisition, funded by the State Coastal Conservancy, currently being pursued. The proposed acquisition includes 213 acres of river bottom, river terrace, and riparian habitat. Staff will remain involved with the Plan's development and implementation. During the fall of 1999, the Project Steering Committee reviewed proposals from consultants to prepare a CEQA document for the Plan for the river.

Regulatory-based Encouragement of Best Management Practices

Currently under consideration are agreements with sister agencies in regulatory-based encouragement of Best Management Practices. Most notably is the use of a GIS layer for pesticides application available from the Department of Pesticide Regulation (DPR). Reduction of pesticides identified as contaminants of concern for a watershed might be addressed through a Management Agency Agreement (MAA) with the DPR, or through waiving adoption of waste discharge requirements on an individual basis using information gathered in databases provided by the Ventura County Agricultural Commission office.

Regulatory involvement with the Agua Dulce septic tank problems is currently at Tier I but is moving into Tier II (see discussion of Nonpoint Source Program in the Regionwide Section for description of tiers). The rural community of Aqua Dulce is at the headwaters of the Santa Clara River in northern Los Angeles County. Previous studies have shown elevated nitrate levels in the groundwater due to animal wastes, septic systems, and some natural sources. Some drinking water wells are experiencing high levels of nitrate exceeding the MCL. The Regional Board requested the Aqua Dulce Town Council submit quarterly monitoring reports with a goal of testing 65 wells each quarter. Quarterly reports so far submitted have shown nitrate contamination.

Agriculture

There are a number of 303(d)-listed impairments in the watershed which may be attributable in part to agricultural practices, notably salts and nitrogen related as well as movement of historic pesticides. We will be focussing our 319(h) priorities for the upcoming application period on a number of areas of concern in the Region including development of an agricultural "strategy", education and outreach programs and implementation of management measures relative to nutrient management and erosion control.

Groundwater

The Oxnard Forebay is a prime groundwater recharge area that is impacted by nitrogen discharges, mainly from densely populated communities using septic systems, and agricultural areas. The Regional Board undertook a study of septic systems in the area during FY98/99; in August 1999 the Board adopted a Basin Plan amendment to prohibit septic systems in the Oxnard Forebay. The amendment immediately prohibits the installation of new septic systems or the expansion of existing septic systems on lot sizes of less than five acres. Discharges from septic systems on lot sizes of less than five acres must cease by January 1, 2008. This prohibition will affect up to 3,000 septic systems and ten to fifteen thousand people.

BASIN PLANNING

Chloride impairments in certain reaches of the river initially led to formation of a chloride committee to conduct a chloride TMDL by spring 2000. This stemmed from issues raised during development of a chloride policy for the region. Growers expressed concerned about increased chloride and effects on salt-sensitive crops, such as avocados. Staff propose going to the Board in December 2000 with two resolutions: one to extend the interim chloride limitation for discharges to the river until December 7, 2001; the other to amend the Basin Plan chloride objective for certain reaches in the river. The Board adopted the extension of the interim limitation at the December meeting, raised the Basin Plan objectives in Reach #3 from 80 to 100 mg/l, and determined the chloride objective for chloride in reaches #7 and #8 should remain unchanged from 100 mg/l. Reaches #3, #7, and #8 are currently 303(d)-listed for chloride. Reach #3, now with a higher objective for chloride, may be considered for de-listing in 2002. The Board has directed staff to complete a chloride TMDL on Reaches #7 and #8 within six to nine months.

Basin Planning activities will also include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

The Santa Clara River Watershed is being proposed for inclusion in a partial update of the Water Quality Assessment report due in 2002. This will require staff resources to collect and analyze data in 2000/01 in order to develop a State of the Watershed Report and update the Water Quality Assessment.
Future phases of the Santa Clara River Enhancement and Management Plan effort, to be carried out over the next one-to-five years, involve completion of the GIS overlay analysis, preparation of the Draft Plan, environmental and public review of the Draft Plan, publication of a Final Plan, and acquisition of funding for Plan implementation. Regional Board staff involvement will continue.

Our efforts to involve stakeholders shall also include exploration of funding options (especially for implementation of nonpoint source measures) and continuation of other outreach activities, such as speeches, meetings, and participation in environmental events. We shall continue out involvement in the watershed group's efforts to develop and implement a watershed management plan.

We are also proposing increased efforts in oversight and management of ground water resources. However, staff involvement in voluntary resolution of nonpoint source problems (Tier I) requires more resources than a regulatory-based approach. Tier II (regulatory encouragement) activities over the long-term include tracking nonpoint source inputs by supplemental databases such as DPR and the Department of Food and Agriculture (DFA), as well as increased sampling of the receiving water for contaminants of concern and toxicity. Tier III (effluent limitations) activities over the long-term include sampling, inspecting, and permitting priority contributors of contaminants of concern in watersheds not fully implementing a stakeholder-driven watershed approach.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. With additional resources we propose conducting a number of education and outreach activities including holding regional workshops and conferences with other Regional Boards as well as experts in the field. We also propose further refining our agricultural strategy to clearly delineate our goals and objectives with regards to reducing nonpoint source pollution from this sector and potential triggers for moving through the tiers.

The complexity of this watershed system, coupled with divergent goals among upstream developers, downstream farmers, and environmental interests, necessitate that extra planning resources be allocated to this watershed. It is imperative that the Regional Board actively participate in dialogue regarding water quality issues during the near-term, to ensure proper planning and development of the long-term projects that are being proposed. Among the various approaches that will be taken by the Regional Board is more active participation in CEQA and other planning efforts in this watershed to ensure protection of this valuable water resource, especially in light of the high growth projections in the floodplains and recharge areas of this watershed.

Potential Mid- to Long-term Activities

- Evaluation of potential impacts from mining in and around the river
- Evaluation of impacts from large-scale development in the upper river
- Identification of conflicts between ground water supply and water quality in lower watershed
- Identification of water quality and quantity issues for steelhead trout recovery
- Consideration of TMDL-related issues
- Implementation of watershed-wide biological monitoring which is a long-term goal for all of our watersheds

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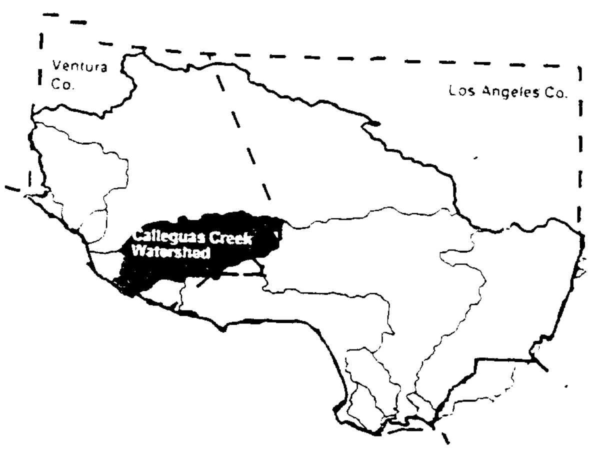
2.2 *CALLEGUAS CREEK WATERSHED*

This was a targeted watershed for permitting purposes in FY95/96 and it will be targeted next in FY01/02.

Overview of Watershed



Calleguas Creek and its major tributaries, Revolon Slough, Conejo Creek, Arroyo Conejo, Arroyo Santa Rosa, and Arroyo Simi drain an area of 343 square miles in southern Ventura County and a small portion of western Los Angeles County. This watershed, which is elongated along an east-west axis, is about 30 miles long and 14 miles wide. The northern boundary of the watershed is formed by the Santa Susana Mountains, South Mountain, and Oak Ridge; the southern boundary is formed by the Simi Hills and Santa Monica Mountains.

Land uses vary throughout the watershed. Urban developments are generally restricted to the city limits of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Although some residential development has occurred along the slopes of the watershed, most upland areas are still open space, however, golf courses are becoming increasingly popular to locate in these open areas. Agricultural activities, primarily cultivation of orchards and row crops, are spread out along valleys and on the Oxnard Plain.

Mugu Lagoon, located at the mouth of the watershed, is one of the few remaining significant saltwater wetland habitats in southern California. The Point Mugu Naval Air Base is located in the immediate area and the surrounding Oxnard Plain supports a large variety of agricultural crops. These fields drain into ditches which either enter the lagoon directly or through Calleguas Creek and its tributaries. Other fields drain into tile drain systems which discharge to drains or creeks. Also in the area of the base are freshwater wetlands created on a seasonal basis to support duck hunting clubs. The lagoon borders on an Area of Special Biological Significance (ASBS)

Beneficial Uses in watershed:

Estuary	*Above Estuary*
Wildlife habitat	Wildlife habitat
Contact & noncontact water recreation	Contact & noncontact water recreation
Estuarine habitat	Industrial service supply
Marine habitat	Industrial process supply
Preservation of rare & endangered species	Preservation of rare & endangered species
Navigation	Agricultural supply
Preservation of biological habitats	Groundwater recharge
Wetlands habitat	Wetlands habitat
Migratory & spawning habitat	Freshwater replenishment
Shellfish harvesting	Warmwater habitat

and supports a great diversity of wildlife including several endangered birds and one endangered plant species. Except for the military base, the lagoon area is relatively undeveloped.

Supplies of ground water are critical to agricultural operations and industry (sand and gravel mining) in this watershed. Moreover, much of the population in the watershed relies upon ground water for drinking.

Water Quality Problems and Issues

Aquatic life in both Mugu Lagoon and the inland streams of this watershed has been impacted by pollutants from nonpoint sources. DDT, PCBs, other pesticides, and some metals have been detected in both sediment and biota collected from surface waterbodies of this watershed. Additionally, ambient toxicity has been revealed in several studies from periodic toxicity testing in the watershed (ammonia from POTWs and pesticides such as diazinon and chlorpyrifos are implicated). Fish collected from Calleguas Creek and Revolon Slough exhibit skin lesions and have been found to have other histopathologic abnormalities. High levels of minerals and nitrates are common in the water column as well as in the groundwater. Sediment toxicity is also elevated in some parts of the lagoon. Reproduction is impaired in the resident endangered species, the light-footed clapper rail due to elevated levels of DDT and PCBs. Overall, this is a very impaired watershed. It appears that the sources of many of these pollutants are agricultural activities (mostly through continued disturbance and erosion of historically contaminated soils), which cover approximately 25% of the watershed along the inland valleys and coastal plain, although the nearby naval facility has also been a contributor. Other nonpoint sources include residential and urban activities, which are present over approximately 25% of the watershed. The remaining 50% of the watershed is still open space although there is a severe lack of benthic and riparian habitat.

Permitted discharges:

- Six POTWs with NPDES permits (3 larger, 3 smaller)
- 82 dischargers covered under an industrial storm water permit
- 100 dischargers covered under construction storm water permit
- Municipal storm water permit

Mugu Lagoon as well as the Calleguas Creek Estuary is considered a candidate toxic hot spot under the BPTCP for reproductive impairment (the endangered clapper rail), exceedance of the state Office of Environmental and Health Hazard Assessment (OEHHA) advisory level for mercury in fish, and exceedance of the NAS guideline level for DDT in fish, sediment concentrations of DDT, PCB, chlordane, chlorpyrifos, sediment toxicity and degraded benthic infaunal community.

Primary issues related to POTW discharges include ammonia toxicity and high mineral content (i.e., salinity), the latter, in part, due to imported water supplies.

<u>Types of permitted wastes discharged into the Calleguas Creek Watershed:</u>

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	2	General
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	2 4	Minor General
Hazardous contaminated groundwater	4 4	Minor General
Nonhazardous (designated) domestic sewage & industrial waste	3 2	Major Minor
Nonhazardous (designated) domestic sewage	1	Minor
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	3	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

Discharges are fairly evenly spread around the watershed; nine of the 25 NPDES discharges go to the Arroyo Conejo, five each to the Arroyo Las Posas and Calleguas Creek, while four go to the Arroyo Simi.

Of the 82 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Electronic and Other Electrical Equipment and Components* and *Stone, Clay, Glass, and Concrete Products* categories.

There are 100 construction sites enrolled under the construction storm water permit. About 60 percent are located in the Simi Valley area and 40% in the Camarillo area. The majority of these are residential sites 10 acres or larger in size.

The table below gives examples of typical data ranges which led to the 1998 303(d) listings. See <u>Table 7</u> in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

IMPAIRMENTS:

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
nitrate + nitrite	Basin Plan numeric objective: no greater than 10 mg/l	11.9 - 70.0 mg/l (mean of 48.5 ± 13)	Fox Barranca Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Calleguas Creek Reach 3 (Potrero to Somis Rd.)
nitrogen	Basin Plan numeric objective: no greater than 10 mg/l		Rio de Santa Clara/Oxnard Drain #3 Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.) Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon Duck pond agric. drain/Mugu Drain/Oxnard Drain #2
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3 - 28.0 mg/l to protect against acute toxicity	0.1 - 20. 2 mg/l (mean of 2.7 ± 3.6)	Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.) Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.) Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.)
algae	Basin Plan narrative objective		Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.)
low DO/org. enrichment	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	2.6 - 10.9 mg/l (mean of 7.0 ± 1.8)	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.)
chlorpyrifos (tissue)	Basin Plan narrative objective		Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.)
toxicity	Basin Plan narrative objective	0 - 100 % survival	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.) Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.) Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.)

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
chloride	Basin Plan numeric objective: 150 mg/l	78 - 230 mg/l (mean of 173 ± 31)	Tapo Canyon Reach 1 Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Calleguas Creek Reach 3 (Potrero to Somis Rd.) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 4 (above Lynn Rd.)
Boron	Basin Plan numeric objective 1.0 mg/l	0.4 - 1.4 mg/l (mean of 1.1 ± 0.3)	Fox Barranca Tapo Canyon Reach 1 Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Arroyo Simi Reach 2 (above Brea Canyon) Calleguas Creek Reach 3 (Potrero to Somis Rd.)
sulfate	Basin Plan numeric objective 250 mg/l	185 - 1000 mg/l (mean of 642 ± 278)	Fox Barranca Tapo Canyon Reach 1 Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Arroyo Simi Reach 2 (above Brea Canyon) Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.)
total dissolved solids	Basin Plan numeric objective 850 mg/l	460 - 1470 mg/l (mean of 1023 ± 246)	Tapo Canyon Reach 1 Fox Barranca Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Arroyo Simi Reach 2 (above Brea Canyon) Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Calleguas Creek Reach 3 (Potrero to Somis Rd.) Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.)
DDT (tissue & sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	37.5 - 1648.0 ng/g (sediment) 145.9 - 556.9 ng/g (tissue)	Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca) Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23)) Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon Rio de Santa Clara/Oxnard Drain #3
chlordane (tissue & sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	3.4 - 45.0 ng/g (sediment) 28.5 - 40.6 ng/g (tissue)	Conejo Creek/Arroyo Conejo N. Fork Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon Rio de Santa Clara/Oxnard Drain #3

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
ChemA* (tissue)	National Academy of Science Guideline (tissue): 100 ng/g	695.9 - 1910.1 ng/g (tissue)	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Rio de Santa Clara/Oxnard Drain #3
dacthal (tissue & sediment)	Basin Plan narrative objective	ND - 120.1 ng/g (sediment) 1.8 - 5.7 ng/g (tissue)	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon
endosulfan (tissue & sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 250 ng/g	ND - 144.2 ng/g (sediment) 42.3 - 294.0 ng/g (tissue)	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon
toxaphene (tissue & sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 8.8 ng/g	ND - 1900 ng/g (sediment) 238 - 468 ng/g (tissue)	Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 4 (above Lynn Rd.) Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon Rio de Santa Clara/Oxnard Drain #3
dieldrin (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 0.65 ng/g	4.7 - 6.6 ng/g (tissue)	Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.)
sediment toxicity	Basin Plan narrative objective	14 - 71 % survival	Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.) Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.) Mugu Lagoon Rio de Santa Clara/Oxnard Drain #3 Duck pond agric. drain/Mugu Drain/Oxnard Drain #2
siltation	Basin Plan narrative objective		Mugu Lagoon
chromium (tissue)	Basin Plan narrative objective	0.51 - 0.58 ug/g (tissue)	Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)

* ChemA refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
silver (tissue)	Basin Plan narrative objective	0.03 - 0.04 ug/g (tissue)	Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)
nickel (tissue)	Basin Plan narrative objective	0.5 ug/g (tissue)	Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd) Mugu Lagoon
cadmium (tissue)	Basin Plan narrative objective	0.14 - 0.15 ug/g (tissue)	Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.) Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit) Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)
copper	USEPA water quality criteria 2.9 ug/l		Mugu Lagoon
zinc	USEPA water quality criteria 86 ug/l		Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Mugu Lagoon
Mercury	USEPA water quality criteria 2.1 ug/l		Mugu Lagoon
Selenium	USEPA water quality criteria 5.0 ug/l	11.0 ug/l (maximum)	Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)
PCBs (tissue & Sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	ND - 96.0 ng/g (sediment) 16.8 - 70.8 ng/g (tissue)	Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon Rio de Santa Clara/Oxnard Drain #3
Trash	Basin Plan narrative objective		Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.)

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
chloride	Tapo Canyon Reach 1 Arroyo Simi Reach 1 Arroyo Las Posas Reaches 1 and 2 Calleguas Creek Reach 3 Conejo Creek Reaches 2 and 4	00/01
nitrogen	Fox Barranca Arroyo Las Posas Reaches 1 and 2 Arroyo Simi Reach 1 Calleguas Creek Reaches 1, 2 and 3 Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reaches 1, 2, 3, and 4 Revolon Slough Main Branch Beardsley Channel Mugu Lagoon Duck pond agric. drain/Mugu Drain/Oxnard Drain #2	02/03
pesticides (water-soluble)	Conejo Creek Reaches 1, 2, 3 and 4 Calleguas Creek Reaches 1 and 2 Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch Beardsley Channel	03/04
Other salts	Fox Barranca Tapo Canyon Reach 1 Arroyo Simi Reaches 1 and 2 Arroyo Las Posas Reaches 1 and 2 Calleguas Creek Reach 3 Conejo Creek/Arroyo Conejo N Fork Conejo Creek Reaches 1, 2, 3 and 4	03/04

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
PCBs	Calleguas Creek Reach 1 Calleguas Creek Reach 2 Revolon Slough Main Branch Beardsley Channel Mugu Lagoon	04/05
pesticides (sediment-bound)	Mugu Lagoon Arroyo Las Posas Reaches 1 and 2 Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reaches 1, 2, 3 and 4 Calleguas Creek Reaches 1 and 2 Duck pond agric. drain/Mugu Drain/Oxnard Drain #2 Revolon Slough Main Branch Beardsley Channel	04/05
metals	Arroyo Simi Reach 1 Conejo Creek Reaches 1, 2 and 3 Mugu Lagoon Revolon Slough Main Branch	05/06

We see a need for an additional 2.5 PYs as well as $50,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Stakeholder Groups

Calleguas Creek Watershed Management Committee (and subcommittees) The committee and subcommittees have been actively meeting since November 1996 with the purpose of developing a watershed management plan. The technical subcommittees include Habitat/Recreation, Flood Protection/Sediment Management, Water Quality/Water Resources, Public Outreach/Education, and Geographical Information Systems (GIS). A Steering Committee attends to the details of management plan development. The full Management Plan Committee meets on a quarterly basis, generally conducting business in a half-day session. Two or three Regional Board staff attend these meetings. The Flood Protection and Habitat Subcommittees meet bimonthly; one Regional Board staff member attends each. The Water Quality Subcommittee is meeting bimonthly and 1-2 staff members attend. The Steering Committee is also meeting bimonthly with 1-2 staff members attending. Regional Board staff are not currently assigned to the Public Outreach and GIS Subcommittees. For further information concerning this group, please visit their website at http://www.calleguas.com/cc.htm.

A number of committee members were also on the *Mugu Lagoon Task Force* which was formed in 1990 in response to concerns about sedimentation filling in Mugu Lagoon which is at the mouth of the Calleguas Creek Watershed. A major focus of the early meetings was exchange of information on the extent of sedimentation with related concerns such as pesticide transfer. A sediment and erosion control plan was prepared for the Ventura County RCD ~~by~~ the U.S. Natural Resource Conservation Service (USNRCS) using Coastal Conservancy funds ("Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon", May 1995). This group is not currently meeting; however, information gained from this effort continues to be used by the other Calleguas Watershed Committees.

Significant Past Activities

CORE REGULATORY

The majority of Calleguas Creek Watershed permits were revised in June 1996. This watershed, as well as the Ventura River Watershed, were pilot watersheds in our implementation of the watershed management approach. The Ventura County Municipal Stormwater NPDES Permit had most recently been adopted in 2000.

MONITORING AND ASSESSMENT

The Calleguas Creek Watershed was included in a partial update of the Water Quality Assessment report in 1998. Also, in 2000, the dischargers completed a short-term watershed characterization study which assessed a large number of sites for both biological and chemical parameters.

BASIN PLANNING

In 1990, the Regional Board adopted Resolution No. 90-004 (**Drought Policy**) which had a term of three years and provided interim relief to dischargers who experienced difficulty meeting chloride objectives because of a state-wide drought. The policy adjusted effluent limits to the lesser of 1) 250 mg/l or 2) the chloride concentration in the water supply plus 85 mg/l. In 1995, the Regional Board extended the interim limits for three years and directed staff to develop a long-term solution to deal with the impact of changing water supply, especially during droughts. In 1997, the Regional Board adopted Resolution No. 97-002 (**Chloride Policy**) which set the chloride objective at 190 mg/l except in the Calleguas Creek and Santa Clara River Watersheds where, due to the great concern for protection of agriculture, staff were directed to determine the chloride concentrations sufficient to protect agricultural beneficial uses.

NONPOINT SOURCE PROGRAM

Work on nonpoint source problems in the watershed has been a long-term effort, initiated in 1990, with the support of 319(h) funds and other funding from, and support by, stakeholders. The 319(h) grant projects, special studies, and other activities that have been completed to date include:

- ***Irrigation Demonstration Project***: In 1994, the Ventura County Resource Conservation District successfully completed an irrigation project that demonstrated the water quality and conservation benefits of drip irrigation. This project was funded through a 319(h) grant.

- ***Toxicity Testing***: In order to detect sources of toxicity, we have collected water samples under three sequential studies (toxicity testing by UC Davis). Results of this sampling indicated sporadic toxicity, generally during wet weather seasons, with strong implication of organophosphate pesticides.

- ***Calleguas Creek Watershed Treatment – Phase I***: The Ventura County Resource Conservation District served as contractor for this project which focused on Best Management

Practices that involved small, individual landowners/ farmers. This demonstration project was designed to implement streambed protection practices. This project was funded through a 319(h) grant.

Current Activities

The following is a summary of current regional board activities in the Calleguas Creek Watershed which are expected to continue as part of the Watershed Management Initiative.

CORE REGULATORY

Permits in this watershed will be targeted for renewal in FY 2001-02. Current regulatory activities include compliance inspections, review of monitoring reports, response to complaints, and enforcement actions, as needed.

A watershed-wide regional monitoring program was created to fill in data gaps and eliminate duplicative and unnecessary monitoring. POTWs contributed significant resources to do a surface and ground water characterization study. It also serves to assess nonpoint source pollution from a variety of land uses.

Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Municipal Storm Water Permit (revised in 2000). Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Ventura County Municipal Storm Water Program. The "Discharger" consists of the co-permittees Ventura County Flood Control District, the County of Ventura, and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks. The Discharger is required to implement the approved Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) by January 27, 2001. The SQUIMP shall address conditions and requirements for new development and significant redevelopment.

The Calleguas Creek receives municipal storm drain discharges from the City of Camarillo, City of Moorpark, City of Simi Valley, City of Thousand Oaks (part), and unincorporated Ventura County (part).

To date, the storm water monitoring program has consisted of land-use based monitoring combined with receiving water monitoring and modeling. The Discharger intends to sign an agreement to participate in the Regional Monitoring Program established for Southern California municipal programs under the guidance of the Southern California Coastal Water Research Project.

In fulfillment of NPDES permit requirements for one discharger, and in concert with other point and nonpoint source dischargers, a characterization study of primarily point source loadings for the pollutants of concern began in June 1998.

Regulation of groundwater protection activities is intended to eventually become fully integrated into the watershed management approach; currently, groundwater monitoring (for POTWs using ponds) is being coordinated with surface water monitoring.

Key regulatory staff continue to participate as past of the Calleguas Creek Watershed team for purposes of updating the State of the Watershed Report and for communication on the characterization study in development.

MONITORING AND ASSESSMENT

Calleguas Creek will be a focus for SWAMP monitoring as the watershed comes up for targeting in the rotating watershed cycle. Since extensive monitoring has already occurred here, particularly in the lower watershed, a more directed approach to sampling site selection will be taken.

As the first integrated watershed monitoring program in the Region, the six POTWs in the watershed are each implementing a portion of the monitoring program as described in their NPDES permits, and as further revised in their Characterization Study to also include other agencies in the effort. In conjunction with the receiving water monitoring, land-use based monitoring is done as a part of the Ventura County Municipal Storm Water Program. The monitoring supports compliance valuation, nonpoint source identification, and potential TMDL development. The expanded monitoring by the dischargers will also serve to evaluate beneficial uses. Additionally, the Regional Board is funding additional toxicity work in the upper watershed in coordination with the dischargers' monitoring.

The BPTCP has identified the lagoon and tidal prism as "toxic hot spots" based on sediment contamination. Staff have completed a cleanup plan for the areas which was adopted as part of a statewide consolidated plan by the State Board in June 1999. Cleanup/remediation alternatives identified include dredging, in-situ capping, and treatment. Continuing Regional Board activities include working with stakeholders to further characterize historical sources of pollution as well as the extent of existing contributions. While remediation of the lagoon (as part of a military facility) may proceed on its own timeline, in general, there is a concerted effort by all stakeholders to prepare a comprehensive watershed management plan to address all problems in the watershed.

Six TMDLs are currently scheduled for this watershed over the next five years and considerable resources will be needed to support their development.

NONPOINT SOURCE PROGRAM

We expect that stakeholders will continue work on developing a watershed management plan, which will include measures for reducing pollutants from nonpoint sources. Accordingly, our efforts in the Calleguas Creek watershed will focus on continuing the nonpoint source phase of the watershed cycle, including integrating results of our on-going nonpoint source efforts. The 319(h) grant projects, special studies, and other activities that are currently on-going include:

319(h) Grant Project

Calleguas Creek Watershed Treatment – Phase II: The Ventura County Resource Conservation District serves as contractor for this project which focuses on Best Management Practices that require the coordinated efforts of several small groups or a large landowner/

farmer (as a followup to Phase I concentrated on small, individual landowners/ farmers). This demonstration project is designed to implement streambed projects that were successful.

We continue to support as high priorities for FY2001/02 319(h) funding projects relating to comprehensive erosion control efforts, habitat enhancement/restoration, and reduction of a variety of pollutants (see Table 4).

205(j) Grant Project

205(j) monies have funded a component of the Surface Water Element of the Calleguas Creek Characterization Study Monitoring Program which is evaluating nonpoint source contributions in the watershed. The study seeks to identify nonpoint source loadings of nitrogen, salts, and pesticides and with the results of the Surface Water Element, conduct TMDLs on several of these pollutants. The study is currently in the data analysis stage.

Toxicity Testing

Followup work is being conducted on the sporadic toxicity found in previous studies conducted by UC Davis. Another contractor is investigating a procedure to distinguish toxicity due to organophosphate pesticides.

Participation in Stakeholder Groups

Calleguas Creek Watershed Management Committee and Technical Subcommittees: Recognizing that many of the water quality problems in the lagoon stem from land use practices and pollutant sources above the lagoon, members of these committees meet regularly to exchange data and discuss coordinated approaches to solving the many problems in this watershed, including development of a watershed management plan. The watershed group consists of about 130 stakeholders who have been meeting for about two years. As we expect that much effort will need to be focussed on resolving agricultural and flood control issues, we have made a concerted effort to include appropriate stakeholders. Besides the main management committee of stakeholders, five technical subcommittees deal with more specific issues such as water quality, flood control, habitat/natural resources, public outreach, and GIS. The group is working on development of a watershed management plan and are actively pursuing development and implementation of "early action" items. Staff have been and will continue to work with these committees.

During fiscal year 2000/01, we shall continue to work with stakeholders to complete a watershed management plan. In particular, we shall work toward integrating our past, on-going, as well as other appropriate nonpoint source projects into the stakeholders' watershed management plan.

Other NPS Activities

Our efforts to involve stakeholders also shall include exploration of funding options (especially for implementation of nonpoint source measures) and continuation of other outreach activities, such as speeches, meetings, and participation in environmental events.

In this watershed, particularly with regards to agriculture, voluntary nonpoint source management measures are taking place. Agriculture is being brought into the watershed process as an important stakeholder and have, under the various subcommittees, brought to the table a number of voluntary best management practices.

Currently under consideration are agreements with sister agencies in regulatory-based encouragement of Best Management Practices. Most notably is the use of a GIS layer for pesticides application available from the Department of Pesticide Regulation (DPR). Reduction of pesticides identified as contaminants of concern for a watershed might be addressed through a Management Agency Agreement (MAA) with the DPR, or through waiving adoption of waste discharge requirements on an individual basis using information gathered in databases provided by the Ventura County Agricultural Commission office.

BASIN PLANNING

A priority basin planning issue is continued work to determine the scope of water quality impacts from agricultural runoff in the Region. The majority of agricultural activities occur in the Calleguas Creek Watershed, especially in the Oxnard Plain and in the nearby foothills. Development of solutions to any impacts is also a high priority and will be a major concern of the nonpoint source program and, by extension, the watershed committee and subcommittees which will be addressing this as well as other problems. An evaluation of salt-sensitive agricultural resources will be done as part of the chloride TMDL.

Chloride impairments in certain reaches of the river led to formation of a chloride committee to conduct a chloride TMDL by spring 2000. This stemmed from issues raised during development of a chloride policy for the region. Growers are concerned about increased chloride and effects on salt-sensitive crops, such as avocados. In December 2000, the Board a resolution to extend the interim chloride limitation (190 mg/l) for discharges to the creek until December 7, 2001. A chloride TMDL for the creek is tentatively scheduled to go before the Board in March 2001.

WETLANDS PROTECTION AND MANAGEMENT

The <u>Southern California Wetlands Recovery Project</u> considers the lower Conejo Creek acquisition a high priority project for funding starting in FY00/01. The Habitat Subcommittee of the Calleguas Creek Watershed Plan Committee has also approved the acquisition as a priority. A conceptual restoration plan is being prepared.

<u>The Santa Monica Mountains Conservancy</u> is a state agency created by the Legislature in 1979 charged with primary responsibility for acquiring property with statewide and regional significance, and making those properties accessible to the general public. The Conservancy manages parkland in the Santa Monica Mountains, Santa Susana Mountains, the Simi Hills, the Santa Clarita Woodlands, the Whittier-Puente Hills, the Sierra Pelona, the Los Angeles River Greenway, the Rio Hondo, the Verdugo Mountains, the San Gabriel Mountains, and the San Rafael Hills. The agency's goals are to: 1) implement the Santa Monica Mountains Comprehensive Plan, 2) implement the Rim of the Valley Trails Corridor Master Plan, 3) implement the Los Angeles County River Master Plan, 4) further cooperation with local governments in the region to secure open space and parkland, and 5) expand education, public

access, and resource stewardship components in a manner that best serves the public, protects habitat, and provides recreational opportunities.

DOD SITE CLEANUP PROGRAM

The Regional Board is working with the Department of Toxic Substances Control (DTSC) to investigate soil and groundwater quality. Sites currently under assessment/remediation include Mugu Lagoon, a former landfill, the Naval Exchange gas station, two Installation Restoration Program (IRP) sites, numerous underground storage tanks, and the former oxidation sewage ponds.

The Navy disposed of inert, contaminated and hazardous wastes to an unlined unpermitted landfill constructed by depositing and compacting wastes into Calleguas Creek. An erosion berm was installed as an interim remedial measure to prevent further erosion of the former landfill by storm water flowing through the creek during storm events. Long-term groundwater monitoring will be required for this site. Sediments and surface water at IRP Site 5 are contaminated with chrome. An initial emergency removal action (sediment excavation) failed to adequately remediate all impacted sediments and additional sediment remediation and surface water monitoring is ongoing.

Soil and groundwater at IRP Site 24 is contaminated with chlorinated solvents. Groundwater is being treated by implementation of a new biodegradation technology. It is not yet determined to what extent groundwater remediation or monitoring will be required to restore this site.

It is anticipated the Navy will implement a base-wide groundwater/surface water investigation to evaluate the overall groundwater and surface water quality, evaluate the interactions of surface water and groundwater, and determine the cumulative risk of multiple groundwater-surface water contamination sites on the overall water quality of the area and the risk to human health and the environment.

Prior to 1979, the Navy was allowed to discharge partially treated wastewater to surface water oxidation ponds that were constructed in the Calleguas Creek tidal prism. The ponds were unlined and allowed to percolate unevaporated water to the underlying groundwater, which is located about four feet below grade. The Regional Board rescinded the Navy's discharge permit in 1979 and required the Navy to pump all wastewater to the Oxnard POTW. However, periodic unpermitted discharges of wastewater continued to the ponds during planned repairs of the wastewater discharge line and wastewater overflow conditions, which occurred during heavy rains.

To prevent additional wastewater discharges to the ponds, the Regional Board issued a Cleanup and Abatement Order to the Navy in 1998 directing the Navy to cease all unpermitted discharges, construct a lined emergency wastewater retention basin, upgrade the wastewater discharge line, and remove the sludge that has accumulated in the ponds.

Current funding for the investigation and remediation of contaminated solids, surface water and groundwater at the base is through the DoD/CalEPA funding agreement; however, this funding is not satisfactory for the investigation or control of contaminants from upstream sources for the protection of Mugu Lagoon and continued funding cuts have had significant impacts on the level of oversight by Regional Board staff on these areas.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

NPDES Permits in the watershed will come up for renewal in FY 2003/04. In the meantime, core regulatory activities will focus on permit compliance, monitoring report review, and enforcement as needed. In addition, integration of stormwater and nonpoint source issues will continue. Members of the watershed team will be involved with periodic updates of the State of the Watershed Report. Additionally, there will be on-going interaction with stakeholders and followup on goals established during the permit renewal phase. Pending results from the discharger pollutant characterization study, a decision on waste load and load allocations will be pursued.

A review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

We shall have made significant progress later in this watershed's first cycle, toward identifying and assessing problems (through the characterization study) and involving stakeholders. At that point we (and the stakeholders) may also enough information to get a headstart on establishing load allocations for certain pollutants of concern.

Additional monitoring and assessment tasks include continued involvement in updates to the baseline State of the Watershed Report, focusing on filling data gaps and evaluating cumulative impacts as monitoring data become available from dischargers, evaluating the results of the the Characterization Study, Regional Board ambient monitoring, follow-up on pollutants identified through toxicity identification evaluations, implement TMDLs to actually begin to solve problems found through monitoring, and implementing the municipal storm water program.

Our efforts to involve stakeholders shall also include exploration of funding options (especially for implementation of nonpoint source measures) and continuation of other outreach activities, such as speeches, meetings, and participation in environmental events. We shall continue our involvement in the watershed group's efforts to develop and implement a watershed management plan.

Additionally, we need to outreach more with the agricultural community. We are also proposing increased efforts in oversight and management of ground water resources. However, staff involvement in voluntary resolution of nonpoint source problems (Tier I) requires more resources than a regulatory-based approach. Tier II (regulatory encouragement) activities over the long-term include tracking nonpoint source inputs by supplemental databases such as DPR and the Department of Food and Agriculture (DFA), as well as increased sampling of the receiving water for contaminants of concern and toxicity. Tier III (effluent limitations) activities over the long-term include sampling, inspecting, and permitting priority contributors of contaminants of concern in watersheds not fully implementing a stakeholder-driven watershed approach. Staff are currently working on an agricultural policy for the board.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate Small Community Grant, State Revolving Fund, 205(j), and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

Potential Mid- to Long-term Activities

In the long-term, activities will include continued participation in both internal and external watershed planning efforts and further implementation of watershed-specific solutions. Several Basin Planning issues will be addressed through the Characterization Study and watershed planning efforts. More resources are needed for these activities in 2000/01 and beyond.

Other mid- to long-term issues include:

- Beneficial uses: Studies to evaluate beneficial use issues.
- Site specific objectives: Review studies conducted by dischargers or other watershed interests.
- Land use planning: Integrate water supply and quality issues with local land use planning and management.
- Groundwater: Integrate inter-related ground and surface waters--optimizing protection for both.
- Flood control: Institute better coordination of multi-agency reviews of environmental impacts for flood control and development projects, including the consideration of regional mitigation programs. Optimize the use of environmentally-friendly flood control facilities.
- Implementation of watershed-wide biological monitoring is a long-term goal for all of our watersheds.

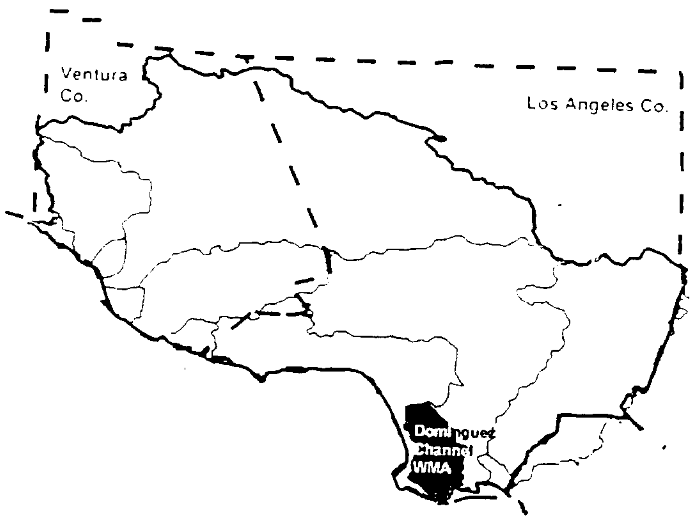
Review and comment on watershed issues in CEQA documents (for the highest priority projects) will also continue; however, this is currently an unfunded program.

Under the BPTCP, we estimated that about 20% of the Western Arm and 10% of the Eastern Arm of Mugu Lagoon contain contaminated sediments (about 725,000 cubic yards). We estimate that about 3 miles of Calleguas Creek contains 50,000 to 100,000 cubic yards of contaminated sediments. We want to work with local groups to develop remediation plans. Due to sensitive nature of Mugu Lagoon, we would suggest no action or in-situ treatment, rather than dredging, as remediation options. Treatment is expensive (probably would exceed $100 per cubic yard). Dredging could be used to remediate Calleguas Creek, although finding a suitable disposal site could be difficult; it would cost $1 to 5 million.

2.3 DOMINGUEZ CHANNEL AND LOS ANGELES/LONG BEACH HARBORS WMA

This watershed will be targeted for permitting purposes in FY02/03.

Overview of WMA



The Los Angeles and Long Beach Harbors are located in the southern portion of the Los Angeles Basin. Along the northern portion of San Pedro Bay is a natural embayment formed by a westerly extension of the coastline which contains both harbors, with the Palos Verdes Hills the dominant onshore feature. Historically, the area consisted of marshes and mudflats with a large marshy area, Dominguez Slough, to the north, and flow from the Los Angeles River entering where Dominguez Channel now drains. Near the end of last century and during the beginning of this one, channels were dredged, marshes were filled, wharves were constructed, the Los Angeles River was diverted, and a breakwater was constructed in order to allow deep draft ships to be directly offloaded and products be swiftly moved. The Dominguez Slough was completely channelized and became the drainage endpoint for runoff from a highly industrialized area. Eventually, the greater San Pedro Bay was enclosed by two more breakwaters and deep entrance channels were dredged to allow for entry of ships with need of 70 feet of clearance. The LA/LB Harbor complex together is now one of the largest ports in the country.

Both harbors are considered to be one oceanographic unit. Despite its industrial nature, contaminant sources, and low flushing ability, the inner harbor area supports fairly diverse fish and benthic populations and provides a protected nursery area for juvenile fish. The California least tern, an endangered species, nests in one part of the harbor complex.

Beneficial Uses in WMA

Dominguez Channel (above estuary)	*Domiguez Channel (in estuary)*
Noncontact water recreation	Contact & noncontact water recreation
Preservation of rare & endangered species	Preservation of rare & endangered species
	Industrial water supply
	Navigation
	Commercial & sportfishing
	Marine habitat
	Estuarine habitat
	Wildlife habitat
	Migratory & spawning habitat

Similar to LA Inner Harbor in many respects, LB Inner Harbor is dissimilar to the other Port in the higher number of privately-owned waterfront parcels which the Port has recently been in the process of the buying up and converting to Port-related uses, generally container terminals. Also, basins and slips in LB Inner

Harbor are somewhat more separated from each other than in LA Inner Harbor which may possibly prevent contamination from spreading easily.

The outer part of both harbors (the greater San Pedro Bay) has been less disrupted and supports a great diversity of marine life. It is also open to the ocean at its eastern end and receives much greater flushing than the inner harbors.

Water Quality Issues and Problems

A POTW discharges secondary-treated effluent to the outer LA/LB Harbor and is under a time schedule order to remove the discharge. The discharger's plan consists of achieving full reclamation (mostly for industrial reuse purposes) by 2020 which would eliminate the discharge completely. They plan on achieving about 80% reclamation by 2005. Two generating stations discharge to the inner harbor areas. Many smaller, non-process waste discharges also occur into the harbors and Dominguez Channel drains a highly industrialized area of the city resulting in very poor water quality.

Permitted discharges:

- One POTW
- Two generating stations
- Six refineries
- 415 dischargers covered under an industrial storm water permit
- 69 dischargers covered under the construction storm water permit

Types of permitted wastes discharged into the Dominguez Channel WMA:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	1 1 1	Major Minor General
Nonhazardous (designated) contact cooling water	2	Minor
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	1 6 30	Major Minor General
Nonhazardous (designated) noncontact cooling water	2 5 2	Major Minor General
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	1	Minor
Nonhazardous (designated) stormwater runoff	2 36	Major Minor
Hazardous contaminated groundwater	6 4	Minor General
Nonhazardous (designated) domestic sewage	1	Major
Nonhazardous (designated) filter backwash brine waters	2	Minor
Nonhazardous wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	2	General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	9	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

About one-half of the 120 NPDES discharges to Dominguez Channel; the rest go to the LA/LB Harbor.

Of the 415 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Motor Vehicle Parts, Used*; *Fabricated Metals Products, Except Machinery and Transportation Equipment*; and *Motor Freight Transportation and Warehousing* categories.

There are 69 sites enrolled under the construction storm water permit. The majority are along Dominguez Channel and are commercial sites.

Potential sources of pollution:

- Historical deposits of DDT and PCBs in sediment
- Discharges from POTW & refineries
- Spills from ships and industrial facilities
- Leaching of contaminated groundwater
- Stormwater runoff

Two areas within Los Angeles Harbor are considered to be toxic hot spots under the BPTCP: Dominguez Channel/Consolidated Slip, based on sediment concentrations of DDT, PCB, cadmium, copper, lead, mercury, zinc, dieldrin, chlordane (all exceed sediment quality guidelines), sediment toxicity, and degraded benthic infaunal community; and Cabrillo Pier area, based on sediment concentrations of DDT, PCB and copper, sediment toxicity and issuance of a human health (fishing) advisory for DDT and PCB in white croaker and exceedances of National Academy of Science guidelines for DDT in fish and shellfish. Several locations have been listed as sites of concern under the BPTCP: Inner Fish Harbor, due to sediment concentrations of DDT, PCB, copper, mercury and zinc and sediment toxicity (not recurrent); Kaiser International, due to sediment concentrations of DDT, PCB, PAH, copper and endosulfan; Hugo Neu-Proler, due to PCB sediment concentrations; Southwest Slip, due to sediment concentrations of DDT, PCB, PAH, mercury, and chromium, and sediment toxicity (not recurrent); Cerritos Channel, due to sediment concentrations of DDT, PCB, metal, chlordane, TBT, sediment toxicity and accumulation in mussel tissue; Colorado Lagoon, due to DDT, PCB, lead, zinc, chlordane, dieldrin, sediment toxicity and accumulation in mussel and fish tissue; Shoreline Marina, due to sediment concentrations of zinc, DDT, PCB, chlordane and PAH, and sediment toxicity (not recurrent); Long Beach Outer Harbor, due to sediment concentrations of DDT and chlordane and sediment toxicity (not recurrent); West Basin, due to sediment concentrations of DDT and PCB, sediment toxicity (not recurrent) and accumulation in clam tissue; Alamitos Bay, due to sediment concentrations of DDT and chlordane. There is need for further monitoring in all of these areas to clarify their status. Potential sources of these materials are considered to be historical deposition, discharges from the nearby POTW (especially for metals), spills from ships and industrial facilities, as well as stormwater runoff. Many areas of the harbors have experienced soil and/or groundwater contamination, which may result in possible transport of pollutants to the harbors' surface waters. Dredging and disposal of contaminated sediments and source control of pollutants in the harbors will be a major focal point for the Contaminated Sediment Task Force described further in the Region-wide Section of this document.

Los Angeles Inner Harbor

Although the area is dramatically cleaner now than twenty-five years ago, parts of LA Inner Harbor are still suffering the effects of historic deposits of pollutants in the sediment and current point and nonpoint source discharges. Fish caught in the East Basin have exhibited histopathological abnormalities (liver lesions). The abnormalities are indicative of aromatic and chlorinated hydrocarbon contamination. There is also significant degradation in the biological community of a part of Inner Harbor with high levels of PCB and DDT; and toxicity of the surface water microlayer of one part of the harbor to a test fish species (larval kelp bass). Additionally, Cal-EPA's Office of Environmental Health Hazard Assessment now advises against consumption of white croaker in the harbor and recommends no more than one meal every two weeks of black croaker, queenfish, and surfperches if caught in the harbor. On the other hand, the benthic community in many other areas of the inner harbor are healthy and sediments, though high in many pollutants, do not cause a great deal of toxicity in controlled lab tests.

LA Inner Harbor is on the 1998 303(d) list due to DDT, metals, PAHs, chlordane, TBT, and PCBs. Some of the contamination in sediment is historic with resuspension potential. Dominguez Channel was the recipient of runoff from the Montrose Chemical Facility which manufactured DDT several decades ago. There are also mostly nonpoint source inputs from several problem sites, spills, and storm drain runoff. The problems tend to be exacerbated by the poor circulation and flushing. The Port is in the process of filling in a large part of Outer Harbor and deepening some channels as part of their "2020 Plan". Pier 400, a 590-acre site of new land created by diking and filling harbor waters, was completed in April 2000. As a result, the potential exists for greater stagnation and more problems from deposition of new contaminants.

Data from the State Mussel Watch (SMW) Program have documented high levels of metals, PCBs, TBT, and PAHs in mussel tissue at several locations in LA Inner Harbor. The Bay Protection and Toxic Cleanup Program (BPTCP) has found a number of inner harbor areas with elevated pollutant levels but a smaller number of those have exhibited sediment toxicity.

Sediment data collected by Regional Board staff, the Port of LA, and various other researchers, have revealed several areas of heavy contamination with metals, PCBs, and DDT, and occasionally PAHs. Regional Board data show that the level of contamination within particular regions of the inner harbor vary considerably from site to site. Additionally, it is difficult to separate the effects of historic contamination from current inputs. Bight'98 included samples within harbors, including a number of stations in LA/LB Harbor; toxicity, sediment chemistry, and benthic data reports should be available early in 2001.

Dominguez Channel

Little recent data exist for the Channel itself even though considerable heavy industrial facilities (including the old Montrose site) are located within the watershed. However, a consultant for Montrose conducted sediment sampling for DDT in the Channel during 1990. EPA, in a letter to Montrose, cited this data and provided a comparison of those values with NOAA's "identified concentrations of DDT in sediment associated with adverse impacts. A sediment level of 3 ppb was associated with adverse impacts in 10% (ER-L) of the data reviewed by NOAA and a level of 350 ppb total DDT was associated with adverse impacts in 50% (ER-M) of the data reviewed by NOAA" (EPA letter to Montrose Chemical Corporation, November 27, 1991). The consultant found DDT levels of 300 - 13,000 ppb in the Channel. EPA stated that adverse impacts in the biological community of Dominguez Channel and Consolidated Slip would be expected.

A Regional Board study conducted in 1975 found that the aquatic biota of the Channel were largely marine in origin and were a continuation of LA Inner Harbor biota. The number and abundance of aquatic species declined with distance inland from the harbor. A fairly abrupt decline in benthic species between Alameda and Wilmington Streets was attributed to the effects of pollution. *Capitella capitata* was one of the most abundant benthic species in the area and is generally associated with polluted areas. An absence of benthic fish species adjacent to one oil refinery was considered to be indicative of oxygen-poor bottom water. There was a degraded benthic community at several stations in Consolidated Slip during BPTCP sampling.

Of major concern in the mid-1980s was discharge of zinc chromate as an additive in cooling water/boiler blowdown. There may have been some justification for that concern. Sediment sampling conducted by Regional Board staff in 1988 revealed zinc levels as high as 447 ppm, chromium as high as 67 ppm, and lead as high as 231 ppm.

Long Beach Inner Harbor

While historic contamination is a definite problem in the older parts of the harbor (including the naval base), Pier J has only recently been constructed, utilizing some highly contaminated dredge material. Some other likely problem sites include: Cerritos Channel with its inputs at times from Consolidated Slip (water generally flows from LB to LA Harbors), a creosote manufacturing site, several oil terminals, a defunct ship repair yard (and several active ones), and the naval base, which is closed, while the attached shipyard remains open.

Contamination in the LB Inner Harbor is known to be sporadic. Little information is available on contamination in Southeast Basin except for TBT water concentrations of up to 380 PPT found in a 1988 statewide study of harbors and low levels of PCBs found in mussel tissue in 1986. The most recent SMW data for the Inner Harbor show some areas of elevated DDT, most notably at those stations located in or near Cerritos Channel.

Moderate PCB levels were found in mussel tissue in front of the creosote facility located in Channel 2 and somewhat higher levels were found in Cerritos Channel which is likely related to its proximity to Consolidated Slip and other LA Harbor point and nonpoint sources. Long Beach Inner Harbor is on the 1998 303(d) list for DDT, PAHs, and PCBs, while San Pedro Bay is listed for DDT, PAHs, PCBs, and some metals.

The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

IMPAIRMENTS:

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Benthic comm. effects	Basin Plan narrative objective		Dominguez Channel Estuary (to Vermont) Los Angeles Harbor: Consolidated Slip Long Beach Harbor (part Main Ch., SE Basin, West Basin, Pier J, and breakwater)
ChemA* (tissue)	National Academy of Science Guideline (tissue): 100 ng/g		Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Machado Lake (Harbor Lake)
chlordane (sediment & tissue)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	100 ng/g (sediment) 5.0 - 11.3 ng/g (tissue)	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Los Angeles Harbor: Consolidated Slip Machado Lake (Harbor Lake)
DDT (sediment & tissue)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	500 - 1,500 ng/g (sediment) 36 - 227 ng/g (tissue)	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Long Beach Harbor (part. Main Ch., SE Basin, West Basin, Pier J, and breakwater) Cabrillo Beach (Inner) San Pedro Bay nearshore and offshore zone: Cabrillo Pier area Los Angeles Harbor: Southwest Slip Machado Lake (Harbor Lake)
PCBs (sediment & tissue)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	500 - 1,000 ng/g (sediment) 42.5 - 90.7 ng/g (tissue)	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Los Angeles Harbor: Southwest Slip San Pedro Bay nearshore and offshore zone: Cabrillo Pier area Cabrillo Beach (Inner) Long Beach Harbor (part. Main Ch., SE Basin, West Basin, Pier J, and breakwater) Machado Lake (Harbor Lake)
aldrin (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 0.33 ng/g		Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont)
dieldrin (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 0.7 ng/g	0.9 - 2.1 ng/g (tissue)	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Machado Lake (Harbor Lake)
sediment toxicity	Basin Plan narrative objective		San Pedro Bay nearshore and offshore zone: Cabrillo Pier area Los Angeles Harbor: Southwest Slip Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Long Beach Harbor (part. Main Ch., SE Basin, West Basin, Pier J, and breakwater)
PAHs (sediment)	Basin Plan narrative objective	2,000 - 15,000 ng/g (sediment)	Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont) Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Long Beach Harbor (part. Main Ch., SE Basin, West Basin, Pier J, and breakwater) San Pedro Bay nearshore and offshore zone Cabrillo Pier area
Chromium (sediment)	Basin Plan narrative objective	100 - 200 ug/g (sediment)	San Pedro Bay nearshore and offshore zone Cabrillo Pier area Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont) Los Angeles Harbor: Consolidated Slip

* ChemA refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Zinc (sediment & tissue)	Basin Plan narrative objective	150 - 510 ug/g (sediment) 110 - 510 ug/g (tissue)	Los Angeles Harbor: Consolidated Slip Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont) Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) San Pedro Bay nearshore and offshore zone Cabrillo Pier area
Lead (sediment)	Basin Plan narrative objective	120 - 122 ug/g (sediment)	Los Angeles Harbor: Consolidated Slip Torrance Carson Channel Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Dominguez Channel (above Vermont) Wilmington Drain
Copper (sediment)	Basin Plan narrative objective	110 - 140 ug/g (sediment)	Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Wilmington Drain Dominguez Channel (above Vermont) Torrance Carson Channel Dominguez Channel Estuary (to Vermont) San Pedro Bay nearshore and offshore zone Cabrillo Pier area
algae, eutroph.	Basin Plan narrative objective		Machado Lake (Harbor Lake)
odors	Basin Plan narrative objective		Machado Lake (Harbor Lake)
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3 - 28.0 mg/l to protect against acute toxicity	ND - 18.0 mg/l	Machado Lake (Harbor Lake) Wilmington Drain Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont)
tributyltin	Basin Plan narrative objective	2,000 ng/g (tissue)	Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater)
coliform	Basin Plan numeric objective: Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	33 - 160,000 MPN/100ml	Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont) Torrance Carson Channel Wilmington Drain
beach closures	Basin Plan narrative objective	2 - 11 days/year closed	Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Cabrillo Beach (Inner)
Trash	Basin Plan narrative objective		Machado Lake (Harbor Lake)

* Chem A refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	303(d) Listed Waters/Reaches	Year Scheduled for Completed (FY)
coliform	Dominguez Channel Dominguez Channel Estuary Torrance Carson Channel Wilmington Drain	01/02
coliform	Cabrillo Pier area Cabrillo Beach (inner)	01/02

We see a need for an additional 1.1 PY as well as $50,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Current Activities

The following is a summary of current regional board activities in the Dominguez Channel Watershed which are expected to continue as part of the Watershed Management Initiative on a watershed basis.

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits. This will be a targeted watershed for the bulk of permit renewal purposes in FY 2002-03. Many permits (refineries, in particular) are being renewed this year because of backlog issues, however. There are eleven major dischargers, 65 significant or minor dischargers under individual permits, as well as 37 dischargers currently covered under general permits (additional information on permits may be found in the Appendix). Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue. A watershed-wide regional monitoring program will be created in anticipation of the next cycle.

Due to limited resources, only the basic regulatory activities are performed: review of dischargers' monitoring reports, minimum necessary inspections and sampling, issuance/ renewal of permits, levels 1 and 2 enforcement actions (noncompliance and violation notification), case handling, and answering inquiries from the public.

MONITORING AND ASSESSMENT

In anticipation of the need for preparation of a State of the Watershed Report during the permit renewal time period, the Board's regional database's charting and mapping capabilities will be utilized to begin an assessment of available water and sediment quality information.

The BPTCP has identified two areas in the harbors as "toxic hot spots" based on sediment contamination. Staff have completed a cleanup plan for these areas; this plan is part of the Consolidated Plan for the state's toxic hot spots approved recently by State Board. Cleanup/ remediation alternatives identified include dredging, in-situ capping, and treatment. Continuing Regional Board activities include working to insure cleanup of contaminated land sites which may affect harbor waters, issuance of waste discharge requirements, where appropriate, and control/treatment of stormwater runoff. Of those areas identified as candidate sediment toxic hot spots, there is about 25,000 to 50,000 cubic yards of contaminated sediments in the Cabrillo Pier area; removal by dredging and disposal would cost 0.5 to $5 million; however, remediation there isn't recommended until Consolidated Slip contaminated sediments are cleaned up. The Consolidated Slip/Dominguez Channel area has about 50,000 cubic yards of contaminated sediments and would take $1 to 5 million to dredge. More sampling would be needed prior to any dredging in order to develop a detailed dredging plan. Also, post-remediation monitoring would be needed. This area is part of an EPA-designated Superfund site and should receive attention under that program within the next few years.

NONPOINT SOURCE PROGRAM

Staff will pursue starting a general stakeholder group in the watershed to address nonpoint source issues. Staff have performed inspections of commercial fishing operations in the Los Angeles Harbor area and educated personnel regarding negative impacts of discharges to the harbor. Since these inspections, staff have initiated some enforcement actions.

Staff is encouraging proposals for Proposition 13 funding for preparation of a watershed management plan.

BASIN PLANNING

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

Comments on watershed issues in CEQA documents for the highest priority projects will continue to be prepared; this is currently an unfunded program.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

Permits in this watershed will be renewed in FY 2002/03. Continuing core regulatory activities include compliance inspections, review of monitoring reports, response to complaints, and enforcement actions as needed relative to the watersheds NPDES permits. A watershed-wide regional monitoring program will be created in anticipation of the next cycle.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

As noted earlier, a large part of this watershed is on the 303(d) list for a variety of pollutants, especially in the sediment. Work conducted through the BPTCP has determined many of these areas support healthy benthic communities and acceptable levels of sediment toxicity. We will initiate discussions with stakeholders in 2000/01 on the best approach to take to resolve the problems noted on the 303(d) list.

The Dominguez Channel and Los Angeles/Long Beach Harbors Watershed is being proposed for inclusion in a partial update of the Water Quality Assessment report due in 2002. **Staff resources (0.75 PY/year) will be needed in 2000/01 and 2001/02 to collect, analyze, and store data for the Water Quality Assessment, State of the Watershed Report, and TMDL development.**

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

Potential Mid- to Long-term Activities

As may be the case in other industrial areas with extensive sediment contamination, development of regional sediment quality guidelines would be very valuable. The CSTF is developing an electronic database of relevant local sediment monitoring data to be used for this purpose. Development of sediment quality guidelines should be completed by January 2003. Basin Planning efforts may be focused on better defining beneficial uses in the area and implementing the State Bays and Estuaries Plan adopted in 2000. We also anticipate discharger requests for development of site-specific objectives for a number of constituents that will be included in the new Bays and Estuaries Plan. An assessment of existing data will be needed as part of this task.

Additional long-term activities include:

- Development of a watershed-wide monitoring program
- Consideration and implementation of TMDL-related issues
- Further evaluate beneficial uses throughout the watershed
- Restoration of habitat following improvements in water quality
- Implementation of biological monitoring
- Explore options for, and implement, sediment cleanup/removal

2.4 SANTA MONICA BAY WMA

This was the targeted watershed for permitting purposes in FY1996/97 and will be targeted again in FY03/04.

Overview of WMA

The Santa Monica Bay Watershed Management Area (WMA), which encompasses an area of 414 square miles, is quite diverse. Its borders reach from the crest of the Santa Monica Mountains on the north and from the Ventura-Los Angeles County line to downtown Los Angeles. From there it extends south and west across the Los Angeles plain to include the area east of Ballona Creek and north of the Baldwin Hills. South of Ballona Creek the natural drainage area is a narrow strip of wetlands between Playa del Rey and Palos Verdes. The WMA includes several watersheds the two largest being Malibu Creek to the north and Ballona Creek to the south. While the Malibu Creek area contains mostly undeveloped mountain areas, large acreage residential properties and many natural stream reaches; Ballona Creek is predominantly channelized, and highly developed with both residential and commercial properties.

As a nationally significant water body, Santa Monica Bay was included in the National Estuary Program in 1989. It has been extensively studied by the Santa Monica Bay Restoration Project (SMBRP) and a watershed plan was developed in 1994. A Santa Monica Bay Watershed Council was formed in 1994 to oversee implementation of the Plan. The Restoration Project staff will be coordinating with Regional Board staff to carry out the Board's watershed approach in the Santa Monica Bay Watershed.

Water Quality Problems and Issues

Though relatively small in its size compared with watersheds in other parts of the country, the Santa Monica Bay WMA embraces a high diversity in geological and hydrological characteristics, habitat features, and human activities. Almost every beneficial use defined in the Basin Plan is identified in water bodies somewhere in the WMA. Yet many of these beneficial uses have been impaired for years. While some of the impaired areas are showing signs of recovery, beneficial uses that are in relatively good condition face the threat of degradation.

Existing and potential beneficial use impairment problems in the watershed fall into two major categories: human health risk, and natural habitat (wildlife) degradation. The former are issues primarily associated with recreational uses of the Santa Monica Bay. The latter are issues associated with terrestrial, aquatic, and marine environments. Pollutant loadings that originate from human activities are common causes of both human health risks and habitat degradation.

Beneficial Uses in the WMA:

All of the beneficial uses defined in the Basin Plan for the Region occur somewhere in this Watershed Management Area except for BIOL (preservation of biological habitats)

Permitted discharges:

- Seven major NPDES permit discharges
- Three POTWs (two direct ocean discharges), one refinery, and three generating stations
- 21 minor discharges
- 166 dischargers covered under general permits
- 147 discharges covered by an industrial storm water permit
- 107 dischargers covered by a construction storm water permit

Of the major NPDES dischargers in the Santa Monica Bay WMA, the three POTWs (particularly the two direct ocean discharges) are the largest point sources of pollutants to Santa Monica Bay. Pollutants from the minor discharges have been estimated to contribute less than two percent of the total pollutants being discharged to the Bay.

Types of permitted wastes discharged into the Santa Monica Bay WMA:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	2 1 4	Major Minor General
Nonhazardous (designated) contact cooling water	1	Major
Nonhazardous (designated) domestic sewage & industrial waste	3	Major
Nonhazardous (designated) domestic sewage	2	Minor
Nonhazardous filter backwash brine waters	1	Minor
Hazardous stormwater runoff	1	Major
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	11 131	Minor General
Nonhazardous (designated) noncontact cooling water	4 1	Minor General
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	2	Major
Nonhazardous (designated) stormwater runoff	1	Minor
Hazardous contaminated groundwater	1 21	Minor General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage)	8	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain nonhazardous wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

The majority of the 196 NPDES discharges to the Santa Monica Bay WMA go to Ballona Creek (160).

Of the 147 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Fabricated Metal Products, Except Machinery and Transportation Equipment*; *Local and Suburban Transit and Interurban Highway Passenger Transportation*; *Motor Freight Transportation and Warehousing*; and *Scrap and Waste Materials* categories.

There are a total of 107 construction sites enrolled under the construction storm water permit. Forty-five of these sites are in the Malibu Creek Watershed with 62 in the rest of the WMA. The sites are fairly evenly divided between commercial and residential.

A considerable number of monitoring programs have been implemented in the Santa Monica Bay WMA, particularly over the last twenty years. Sampling efforts tend to center around assessing urban runoff effects in general along the coastline and reservoirs of PCBs and DDT contaminated sediment in the area of the Palos Verdes Shelf. Three statewide monitoring programs, State Mussel Watch, Bay Protection and Toxic Cleanup, and Toxic Substances Monitoring, focus on biological measurements.

The data from these programs indicate that in general the open coastline is much cleaner than the Bay's enclosed waters, except with regards to DDT and PCBs on the Palos Verdes Shelf. Pollutants of particular concern are chlordane, DDT, copper, and zinc. The BPTCP has listed the Santa Monica Bay - Palos Verdes Shelf area as a toxic hot spot for DDT and PCBs human health advisories (fishing) and NAS exceedances of DDT levels in fish. Marina Del Rey is listed as a toxic hot spot due to sediment concentrations of DDT, PCB, copper, mercury, nickel, lead, zinc and chlordane, and sediment toxicity; Marina Del Rey Entrance Channel (mouth of Ballona Creek) is listed due to sediment concentrations of DDT, zinc, lead, chlordane, dieldrin, and chlorpyrifos, and sediment toxicity. The BPTCP listed King Harbor as a site of concern, due to sediment concentrations of DDT and PCB and sediment toxicity (not recurrent).

Urbanization has had a significant impact on the riparian and wetland resources of the watershed, primarily through filling, alteration of flows, and decrease in water quality. It is estimated that 90% of the historic wetlands of the Santa Monica Bay WMA have been destroyed, with the remaining wetlands significantly degraded.

Although groundwater accounts only a limited portion of the Santa Monica Bay WMA's supply of fresh water, the general quality of groundwater in the watershed has degraded from background levels.

Greater Santa Monica Bay

Santa Monica Bay is heavily used for fishing, swimming, surfing, diving etc, activities classified as water contact recreation (REC-1). However, the ability for people to enjoy these activities has been lost to a certain degree because of the real or perceived risk to human health. The primary, and also the best documented, problems are acute health risk associated with swimming in runoff-contaminated surfzone waters, and chronic (cancer) risk associated with consumption of certain sport fish species in areas impacted by DDT and PCB contamination.

The general public has also been concerned about potential health risks associated with the consumption of contaminated seafood from Santa Monica Bay. This is the primary pathway through which humans are exposed to toxic chemicals found in the marine environment. While recent studies have shown that health risks are limited to consumption of certain seafood species found at certain locations, the public perception remains that all seafood in the Bay is contaminated.

One of the most evident impacts in marine habitats is sediment contamination and damage to marine life that the contaminants cause when they are released from the sediment (through natural fluctuations or through disturbance of the sediment) into the food chain. Organic compounds such as DDT, PCBs, polycyclic aromatic hydrocarbons (PAHs), chlordane, and tributyltin (TBT) are found in sediments in concentrations that are harmful to marine organisms at various locations in the Bay. Also found in Bay sediments are heavy metals such as cadmium, copper, chromium, nickel, silver, zinc, and lead. The major historic sources of sediment contamination have been wastewater treatment facilities; thus the accumulations are highest near treatment plant outfalls off of Palos Verdes and Playa del Rey.

Major Issues of Concern in Greater Santa Monica Bay

- Acute health risk associated with swimming in runoff-contaminated surfzone waters
- Chronic risk associated with consumption of certain sport fish species in areas impacted by DDT and PCB contamination
- Reduction of loadings from the two major POTWs in light of projected population increases
- Other impacts from urban runoff/storm water
- Historic deposits of DDT and PCBs in sediment; high levels in fish (Palos Verdes Shelf a Superfund site)
- Loadings of pollutants from other sources: sediment resuspension, atmospheric deposition
- The need to have a better understanding of the Bay's resources

Bioaccumulation of DDT in white croaker, dover sole, and California brown pelicans are well-known examples of the impacts caused by sediment contamination. Prior to the 1980s, high concentrations of DDT were found in muscle tissues of these organisms. DDT in these organisms are implicated in fin erosion and other diseases in fish as well as eggshell thinning and subsequent species decline in the California brown pelican.

Malibu Creek Watershed

The most recent Water Quality Assessment Report finds water quality in some streams within the Malibu Creek Watershed is impaired by nutrients and their effects, coliform and their effects, trash, and, in some instances, metals. While natural sources contribute, nonpoint source pollution from human activities is strongly implicated including ill-placed or malfunctioning septic systems and runoff from horse corrals. Nutrient inputs are also contributed by urban runoff and the POTW which discharges tertiary-treated effluent into the Creek about five miles upstream of Malibu Lagoon.

Major Issues of Concern in Malibu Creek Watershed

- Excessive freshwater, nutrients, and coliform in lagoon; contributions from POTW
- Urban runoff from upper watershed
- Impacts to swimmers/surfers from lagoon water
- Septic tanks in lower watershed
- Appropriate restoration and management of lagoon
- Access to creek and lagoon by endangered fish (steelhead trout and tidewater goby)

A nutrient TMDL for the mainstem of the Creek is in progress although ecologically-relevant nutrient objectives are lacking. A recently completed study produced a report which should lead to more effective management of the Lagoon and its resources as the restoration process continues.

Historically, the Lagoon was much larger than its current day size and although the flow dynamics of the Creek as well as the ocean's influence on the Lagoon in the past can only be extrapolated, it is likely Creek flow was much less than today during the dry season and a marine influence may have dominated, keeping the lagoon entrance open much of the year as occurs in the larger Mugu Lagoon to the north.. This also would have facilitated migration of the now endangered steelhead trout. And though Creek flow was likely less, more of the watershed was available for the trouts' use, at least prior to the construction of Rindge Dam in the 1920's. Most important, during the dry season there would be access to deep shaded pools in many parts of the watershed where the fish could mature until rain created the flows needed to reach the ocean.

Today, the flow regime is quite different and a major issue of concern. Both increased urban runoff from the more developed upper watershed and discharges from the POTW have increased baseline flows. However, recently the POTW which discharges to Malibu Creek came under a discharge prohibition starting each May 1, or at the first natural closure of Malibu Lagoon by sand buildup (whichever is later), through and including October 31 of each year, except during times of plant upset, storm events, or the existence of minimal streamflow conditions that require flow augmentation in Malibu Creek to sustain endangered species. In the long-run, this discharge prohibition may have many other implications on water quality and quantity in the Creek and Lagoon.

The lagoon size is much reduced from historic times and it currently remains closed much of the year except for during the winter when ocean influences breach the sandbar and Creek flows help maintain the opening. This had led to decreasing salinity or, at times, greatly fluctuating salinity which has disturbed efforts to restore the Lagoon. This also leads to elevated groundwater levels adjacent to the lagoon, assuring failure of septic systems in the area. Additionally, surfing and swimming is popular off the beaches in the immediate area and there is considerable concern over contaminated Lagoon water reaching these people.

Ballona Creek Watershed

The most recent Water Quality Assessment Report indicates impairment in this watershed due to coliform and its effects such as shellfish harvesting advisories; trash; PCBs and pesticides of historical origin such as DDT, chlordane, and dieldrin, as well as their effects such as sediment toxicity; metals such as lead, silver, arsenic, copper, cadmium, and zinc, as well as their effects such as water column toxicity; and tributyltin.

Ballona Creek is completely channelized to the ocean except for the estuarine portion which has a soft bottom. While at one time it drained into a large wetlands complex, it now has no direct connection to the few wetlands remaining in the area although tide gates exist in the channel which connect to Ballona Wetlands. However, Ballona Creek may more often affect the nearby wetlands due to wave action moving trash, suspended material and dissolved contaminants from the ocean to the nearby Ballona Wetlands and Marina del Rey Harbor within which complex Ballona Lagoon is located.

Major Issues of Concern in Ballona Creek Watershed and Wetlands
• Trash loading from creek • Wetlands restoration • Sediment contamination by heavy metals from creek to Marina del Rey Harbor and offshore) • Toxicity of both dry weather and storm runoff in creek • High bacterial indicators at mouth of creek

The U.S. Army Corps of Engineers (USACE) and Los Angeles County Department of Beaches and Harbors conduct routine dredging operations in order to keep the entrance to Marina del Rey Harbor open. Led by the Los Angeles Basin Contaminated Sediment Task Force (for further information on this Task Force, see the Regionwide Section of this document), the USACE is conducting a study to identify sources of heavy metals loadings within the watershed. The results of the study could provide useful information to develop a TMDL for selected heavy metals.

Both dry weather and storm runoff from the main channel and two major tributaries were found to be toxic to marine organisms. Toxicity was also found during storms in the ocean near the mouth of the Creek. Preliminary investigations show that the sources of toxicity vary, and were associated with metals on one occasion and with organic chemicals on another occasion. Further efforts are needed to identify the sources of toxicity.

Bacterial indicator levels measured at stations near the mouth of Ballona Creek frequently exceed the level of concern. As a result, warning signs are posted permanently on each side of the Creek. The number of beach closures due to sewage spills rose again in 1998 after a long declining trend over the last ten years.

The BPTCP lists the Marina del Rey Entrance Channel and Marina del Rey back channels as Toxic Hot Spots; however, since they are not high priority sites, we have not yet developed preliminary remediation plans or cost estimates.

Other Urban Watersheds

The most recent Water Quality Assessment Report indicates impairment in many of these smaller drainages, which discharge directly to the ocean, due to one or several of the following: coliform, ammonia, lead, copper (and toxicity likely associated with metals), trash, and low dissolved oxygen. Due to the frequency of high bacterial indicator levels, warning signs are posted permanently at many of these locations (i.e., storm drain outlets). It should be noted that there are plans to divert many of these storm drains to the sewer system during dry weather.

IMPAIRMENTS:

The table below gives examples of typical data ranges which led to the 1998 303(d) listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
beach closures	Basin Plan narrative objective	1 - 15 days/year closed	Marina Del Rey Harbor Beach
swimming restrictions	Basin Plan narrative objective		Santa Monica Bay beaches
shellfish harvesting adv	Basin Plan narrative objective		Malibu Lagoon
enteric viruses	Basin Plan narrative objective		Malibu Lagoon Ballona Creek Estuary Malibu Lagoon Pico Kenter Drain
pathogens	Basin Plan narrative objective		Ballona Creek
coliform	Basin Plan numeric objective. Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	Exceedances occurring on up to 53% of sample dates	Palos Verdes Shoreline Point Beach Marina Del Rey Harbor Beach Marine del Rey Harbor - Back Basins Medea Creek Reach 2 (abv. confl. with Lindero) Medea Creek Reach 1 (lake to confl. with Lindero) Las Virgenes Creek Malibu Lagoon Malibu Creek: lagoon to Malibu Lake Stokes Creek Lindero Creek Reach 1 Lindero Creek Reach 2 (above lake) Palo Comado Santa Monica Bay beaches Santa Monica Canyon Ashland Avenue Drain Sepulveda Canyon Pico Kenter Drain Ballona Creek Estuary Ballona Creek
algae	Basin Plan narrative objective		Malibu Creek: Lagoon to Malibu Lake Las Virgenes Creek Lindero Creek Reach 2 (above lake) Medea Creek Reach 2 (abv. confl. with Lindero) Medea Creek Reach 1 (lake to confl. with Lindero) Lindero Creek Reach 1 Malibou Lake Lake Lindero Westlake Lake Lake Sherwood
eutroph.	Basin Plan narrative objective		Malibu Lagoon Malibou Lake Lake Lindero Westlake Lake Lake Sherwood
unnatural scum/foam	Basin Plan narrative objective		Malibu Creek: lagoon to Malibu Lake Las Virgenes Creek Lindero Creek Reach 2 (above lake) Lindero Creek Reach 1
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3-28.0 mg/l to protect against acute toxicity	ND - 5.77 mg/l	Westlake Lake Lake Sherwood Sepulveda Canyon Pico Kenter Drain
odors	Basin Plan narrative objective		Lake Lindero

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Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
low DO, organic enrichment	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	0.1 - 19.3 mg/l (mean of 4.9 ± 4.5)	Las Virgenes Creek Malibou Lake Westlake Lake Lake Sherwood Ashland Avenue Drain
trash	Basin Plan narrative objective		Ballona Wetland Ballona Creek Medea Creek Reach 2 (abv. confl. with Lindero) Medea Creek Reach 1 (lake to confl. with Lindero) Lake Lindero Lindero Creek Reach 2 (above lake) Lindero Creek Reach 1 Malibu Creek: lagoon to Malibu Lake Las Virgenes Creek Pico Kenter Drain
mercury (water & tissue)	USEPA water quality criteria: 0.012 ug/l State Board numeric objective (tissue): Max. Tissue Residue Level 1,000 ng/g	1.0 ug/l (maximum - water)	Santa Monica Bay Nearshore and Offshore Zone Lake Sherwood Triunfo Cyn Creek Reach 1 Triunfo Cyn Creek Reach 2
lead (water & sediment)	Basin Plan narrative objective USEPA water quality criteria: varies based on hardness but typically 3.2 - 25 ug/l	100 - 306 ng/g (sediment) 91 - 240 ug/l (water)	Marina del Rey Harbor - Back Basins Topanga Cyn Creek Sepulveda Canyon Pico Kenter Drain Santa Monica Bay Nearshore and Offshore Zone Ballona Creek Ballona Creek Estuary Santa Monica Canyon Westlake Lake Triunfo Cyn Creek Reach 1 Triunfo Cyn Creek Reach 2
cadmium (sediment)	Basin Plan narrative objective		Ballona Creek Santa Monica Bay Nearshore and Offshore Zone
copper (sediment, tissue, & water)	Basin Plan narrative objective USEPA water quality criteria: varies based on hardness but typically 12 - 47 ug/l	100 ng/g (tissue) 117 - 293 ug/l (water)	Santa Monica Bay Nearshore and Offshore Zone Marina del Rey Harbor - Back Basins Ballona Creek Pico Kenter Drain Westlake Lake Malibou Lake Lake Calabasas
nickel (sediment)	Basin Plan narrative objective		Santa Monica Bay Nearshore and Offshore Zone
silver (sediment)	Basin Plan narrative objective		Santa Monica Bay Nearshore and Offshore Zone Ballona Creek
arsenic (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 200 ng/g		Ballona Creek Ballona Wetland
zinc (tissue & sediment)	Basin Plan narrative objective	500 ng/g (sediment) 500 ng/g (tissue)	Santa Monica Bay Nearshore and Offshore Zone Marina del Rey Harbor - Back Basins Ballona Creek Estuary Lake Calabasas
selenium (water)	USEPA water quality criteria: 5.0 ug/l	8 - 38 ug/l	Lake Lindero Medea Creek Reach 2 (abv. confl. with Lindero) Medea Creek Reach 1 (lake to confl. with Lindero) Las Virgenes Creek Lindero Creek Reach 2 (above lake) Lindero Creek Reach 1
tributyltin (sediment & tissue)	Basin Plan narrative objective	6,000 ng/g (tissue)	Ballona Creek Marina del Rey Harbor - Back Basins
toxicity	Basin Plan narrative objective		Ballona Creek Ashland Avenue Drain Pico Kenter Drain

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
benthic comm. effects	Basin Plan narrative objective		Marina del Rey Harbor - Back Basins Malibu Lagoon
fish consumption advisory	Basin Plan narrative objective		Santa Monica Bay Nearshore and Offshore Zone Marina del Rey Harbor - Back Basins
sediment toxicity	Basin Plan narrative objective		Santa Monica Bay Nearshore and Offshore Zone Marina del Rey Harbor - Back Basins Ballona Creek Ballona Creek Estuary
ChemA*	National Academy of Science Guideline (tissue) 100 ng/g		Ballona Creek
PAHs (sediment)	Basin Plan narrative objective	5000 - 6509 ng/g	Ballona Creek Estuary Santa Monica Bay Nearshore and Offshore Zone
DDT (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	52 - 88 ng/g	Marina del Rey Harbor - Back Basins Ballona Creek Estuary Ballona Creek Santa Monica Bay Nearshore and Offshore Zone Santa Monica Bay beaches
pesticides	Basin Plan narrative objective		Palos Verdes Shoreline Point Beach
PCBs (sediment & tissue)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	200 ng/g (sediment) 29 - 162 ng/g	Marina del Rey Harbor - Back Basins Ballona Creek Estuary Ballona Creek Malibou Lake Santa Monica Bay Nearshore and Offshore Zone Santa Monica Bay beaches
dieldrin (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 0.65 ng/g	4.8 - 16.8 ng/g	Ballona Creek Marina del Rey Harbor - Back Basins
chlordane (tissue & sediment)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	100 ng/g (sediment) 15.3 - 55 ng/g (tissue)	Ballona Creek Santa Monica Bay Nearshore and Offshore Zone Ballona Creek Estuary Marina del Rey Harbor - Back Basins Westlake Lake Malibou Lake
exotic vegetation	Basin Plan narrative objective		Ballona Wetland
habitat alteration, hydromodification, reduced tidal flushing	Basin Plan narrative objective		Ballona Wetland
debris	Basin Plan narrative objective		Santa Monica Bay Nearshore and Offshore Zone
chloride	Basin Plan numeric objective: 250 mg/l	89 - 330 mg/l (mean of 244 ± 76)	Lake Lindero
specific conductance	Basin Plan narrative objective	1325 - 3530 mg/l (mean of 2937 ± 747	Lake Lindero

* ChemA refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
trash	Ballona Wetland Ballona Creek	00/01
Nutrients and their effect	Malibu Lagoon Malibu Creek: Lagoon to Malibu Lake Lindero Creek Reaches 1 and 2 Las Virgenes Creek Medea Creek Reaches 1 and 2 Malibou Lake Lake Lindero Westlake Lake Lake Sherwood	01/02

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
coliform and its effect	Medea Creek Reaches 1 and 2 Lindero Creek Reaches 1 and 2 Las Virgenes Creek Malibu Lagoon Malibu Creek: lagoon to Malibu Lake Stokes Creek Palo Comado	01/02
coliform and its effect	Greater Santa Monica Bay beaches Santa Monica Canyon Ashland Avenue Drain Sepulveda Canyon Pico Kenter Drain	01/02
nutrients and their effect	Medea Creek Reach 2 Lindero Creek Reaches 1 and 2 Las Virgenes Creek Malibu Lagoon Malibu Creek: lagoon to Malibu Lake Malibu Lake Lake Lindero Westlake Lake Lake Sherwood Lake Calabasas	01/02
coliform and its effect	Marina Del Rey Harbor Beach Marine del Rey Harbor - Back Basins	02/03
metals and their effects	Ballona Creek Ballona Creek Estuary Ballona Wetland	02/03
coliform and its effect	Ballona Creek Estuary	02/03
Metals	Santa Monica Bay Nearshore and Offshore Zone	03/04
hist. PCBs, pest. and effects	Marina del Rey Harbor - Back Basins	03/04
hist. PCBs, pest. and effects	Ballona Creek Ballona Creek Estuary	04/05
Metals	Marina del Rey Harbor - Back Basins	04/05

We see a need for an additional 4.2 PYs as well as $230,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Stakeholder Groups

- *Malibu Creek Watershed Advisory Council and Executive Committee (with subcommittees)* A number of stakeholder groups began meeting in the late 1980's/early 1990's in the Malibu area. One short-term facilitated group (in conjunction with the Advisory Council) formulated a list of priority issues that need to be resolved while the Executive Committee worked with the Advisory Council to exchange information and develop a Natural Resources Plan for the watershed prepared by the USNRCS. Separate task forces and subcommittees formed and reformed and eventually one group emerged with its associated subcommittees (and task forces as needed) as the main stakeholder forum. The Malibu Lagoon Task Force is currently quite active and the group is involved with offering advice on watershed-wide monitoring and coordination on development of a Malibu Lagoon Enhancement and Management Plan. Also currently active is the Volunteer Water Quality Monitoring Task Force, Monitoring and Modeling Subcommittee (tasked with developing a watershed-wide monitoring program), Human Health Subcommittee, and Wildlife Subcommittee. Joint Advisory Council/Executive Committee meetings occur quarterly with 1-2 staff members attending. Various subcommittees and task forces are active as needed but usually 1-2 other groups will be meeting quarterly with 1-2 staff members attending.

- *Santa Monica Bay Restoration Project (Watershed Council, Bay Oversight Committee, Implementation Committee, and Technical Advisory Committee)* The SMBRP was formed in 1989 under the National Estuary Program and is charged with the responsibility of assessing the Bay's problems, developing solutions, and identifying implementation procedures. A Bay Restoration Plan was developed and is in the process of being implemented. One or two Regional Board staff will attend the quarterly meetings of the Oversight Committee while another staff member will attend the quarterly Technical Advisory Committee meetings. More information about this group may be found at their website http://www.smbay.org/.

- *Topanga Watershed Committee* The committee was formed in 1998 as a followup to previous a community group working developing on alternatives to traditional flood control measures. Their focus has expanded to include general watershed management and protection activities as well as volunteer monitoring. More information about this group may be found at their website http://www.topangaonline.com/twc/index.html.

Past Significant Activities

Watershed Management

The first edition of a State of the Watershed Report was produced in June 1997 which assessed water quality using data from the SMBRP and the Regional Board as well as other data provided by Watershed Council members; this document will continue to evolve and be updated.

Nonpoint Source

A number of nonpoint source control strategies have been undertaken in the Malibu Creek Watershed. Those that involved restoration of aquatic life beneficial uses include streambank and riparian corridor habitat restoration projects funded by 319(h) monies undertaken by the Resource Conservation District of the Santa Monica Mountains and the Department of Parks and Recreation. Additionally, the Resource Conservation District has prepared a manual for horse owners in the areas detailing ways to prevent nonpoint source inputs from their land (funded by 319(h) monies).

Current Activities

The following is a summary of current regional board activities and strategies for dealing with point and nonpoint source pollution as well as other issues of concern in the Santa Monica Bay WMA.

CORE REGULATORY

Revisions of most of the major permits took place during 1997. Many of the minor discharges are now regulated under general permits. Portions of a regional ocean monitoring program are currently being implemented and other aspects of it are being developed (see Region-wide Section for additional details). Watershed (inland) regional monitoring programs are being developed with the dual purpose, in many instances, of both creating a more effective program and collecting the needed data to determine mass loading allocations. Ongoing work related to individual NPDES permits includes review and assessment of monitoring data, conducting compliance inspections, and pursuing enforcement actions if necessary. Due to limited resources, only the basic regulatory activities are performed: review of dischargers' monitoring reports, minimum necessary inspections and sampling, issuance/renewal of permits, levels 1 and 2 enforcement actions (noncompliance and violation notification), case handling, and answering inquiries from the public.

Core regulatory responsibilities also include administration of the consent decrees for full secondary treatment compliance by the City of Los Angeles and the County Sanitation Districts of Los Angeles County (CSDLAC) and a 1990 Settlement Agreement with the City of Los Angeles. Another responsibility is oversight of the approved pretreatment programs for the joint outfall system for the City of Los Angeles and the CSDLAC and oversight of the sewage collection systems.

In addition, although the permit for the Tapia Water Reclamation Plant in the Malibu Creek Watershed was renewed in 1997, there were appeals and changes which resulted in the permit being revised again in December 1999. Staff continue to spend significant effort on this permit due to contentious issues such as the summer flow prohibition and pending nutrient limitations.

The Santa Monica Bay WMA falls within Los Angeles County which was issued a renewed municipal storm water permit in 1996. There are 87 co-permittees covered under this permit including 85 cities, the County of Los Angeles, and the California Department of Transportation (Caltrans). Work on the permit will involve review of monitoring reports, evaluation of the storm water program's effectiveness, coordination with other watershed efforts, and modification of the permit as necessary. During 1997/98, discharger responsibilities under the permit concentrated on the evaluation of the five BMP model programs required in the 1996 permit: Illicit Connection/Illicit Discharges, Development Construction, Development Planning, Public Agency Activities, and Five-Year Public Education Strategy (including industrial/commercial site visits).

However, the Regional Board also needs to encourage and support the development and implementation of innovative structural and non-structural BMPs under the municipal storm water permit. In the Ballona Creek Watershed, over the next two years, many projects funded under Proposition A will be implemented. Promoted by the SMBRP, co-permittees within the watershed have collaboratively or individually conducted pilot projects to test new catchbasin retrofit devices and the effectiveness of street sweeping methodologies. The City of Los Angeles also conducted a study of impacts of street washing in homeless-aggregated areas. The results of these studies/pilot projects may lead to possible wide application of some new BMPs over the next two years. These projects would qualify to receive Section 319(h) funding.

An important requirement of the storm water municipal permit is implementation of the Standard Urban Storm Water Mitigation Plans (SUSMPs) and Numerical Design Standards for Best Management Practices (BMPs) which were adopted in 2000. The SUSMP is designed to ensure that storm water pollution is addressed in one of the most effective ways possible, i.e., by incorporating BMPs in the design phase of new development and redevelopment. It provides for numerical design standards to ensure that storm water runoff is managed for water quality concerns in addition to flood protection and that pollutants carried by storm water are retained and not delivered to waterways.

The numerical design standard is that post-construction treatment BMPs be designed to mitigate (infiltrate or treat) storm water runoff from the first ¾ inch of rainfall, prior to its discharge to a storm water conveyance system. Other standards also apply; additional information on the SUSMP may be found on the Regional Board website http://www.swrcb.ca.gov/~rwqcb4.

Also, given the recent surge in sewage spills into Ballona Creek, the Regional Board needs to exercise its authority through use of enforcement actions to require the City of Los Angeles to complete its planned infrastructure improvement and enhance its vigilance over the existing sewer system.

Key regulatory staff will also remain involved in the Santa Monica Bay team in order to stay focused on key watershed issues and contribute to updates of the State of the Watershed Report.

MONITORING AND ASSESSMENT

Portions of a regional ocean monitoring program are currently being implemented and other aspects of it are being developed (see Regionwide Section for additional details). Watershed (inland) regional monitoring programs are being developed with the dual purpose, in many instances, of both creating a more effective program and collecting the needed data to determine mass loading allocations. Bight'98 and 1994 SCBPP monitoring covered coastal areas (including harbors and marinas in Bight'98).

The SMBRP, with participation of the Regional Board, has been developing a new sources and loading monitoring design for point and nonpoint source ocean discharges from the Santa Monica Bay WMA/wasteshed. The overall objective of this monitoring program design, which applies to any watershed, is to produce improved estimates of loadings to the Bay in order to:

- make cost-effective trade-offs in reducing inputs of toxic pollutants
- evaluate the effectiveness over time of source control and treatment options taken to reduce inputs to the Bay
- assist in evaluating receiving water impacts

Because it is not practical to continuously monitor every stream/storm drain, the monitoring approach adopted by the municipal storm water permit is to rely on sampling of a set of mass loading stations in combination with a set of land use stations. Data collected through sampling of these stations will then be used to calibrate models that produce mass loading estimates for a specific watershed/subwatershed. This approach is further supplemented by several monitoring programs and research projects with narrower objectives. Under the municipal storm water permit, the Los Angeles County Department of Public Works (LAC-DPW) is conducting a critical source monitoring project to estimate the relative loading from five selected facilities/sites with high potential of generating pollutants. Caltrans conducts monitoring aimed at estimating loadings from highway runoff. For the last two years, LAC-DPW has funded USC/UCBS/SCCWRP to define the dispersion zone of storm water in the nearshore ocean and to study impacts from storm water runoff by measuring sediment contamination, toxicity, and the benthic community response index in the dispersion zone. The USACE has worked with UCLA to collect storm water samples in Ballona Creek to calculate relative contributions of pollutant loadings from each tributary and major land use types. SCCWRP also has on-going efforts to investigate the loading and impacts of storm water runoff throughout the Southern California region, including creeks in the Santa Monica Mountains.

Besides information provided by these existing efforts, there are still information gaps that hinder the fulfillment of the identified monitoring objectives. Specifically, the following needs to happen during the next two years:

- A project that develops methodology for and conducts status and trend analysis using stormwater monitoring data collected under the municipal NPDES permit.
- A study that uses more frequent monitoring during different periods of a storm to generate a "pollutograph." This information will greatly improve the accuracy of pollutant loading estimates generated by modeling efforts.
- A project that resolves the issue of consistency in detection limits used by different dischargers. The Regional Board needs recommendations and rationale on the proper detection limits for each measured constituent to estimate and make comparisons of loadings from various sources (point and nonpoint sources).
- The study and application of molecular markers for storm water runoff. The marker can be used to identify the area of storm water influence and therefore aid further study if the runoff impacts in receiving water sediments.
- Toxicity Identification Evaluations to identify the sources of storm water/urban runoff toxicity.
- A study of the effectiveness of structural BMPs that are implemented using Proposition A grant money funds. Since many pollution control devices are new and considered to be pilots in the Region, the review panel for the Proposition A funds recommended that the regional Board should take on the responsibility to both monitor the progress in implementing these projects and to evaluate the effectiveness of installed devices for regional applicability.
- A study of the effectiveness of non-structural BMPs (e.g. public outreach) implemented under the municipal storm water permit. The information will be useful for developing future storm water pollution control strategies.
- Development of practical sanitation survey tools.

These projects would require either additional staff time or need to receive funding from sources such as Section 205(j) grants, State Revolving Fund (SRF), or Proposition 13.

A marine resource inventory and habitat mapping (available on CD) are two projects recently completed for Santa Monica Bay. The objectives of these projects are to produce a detailed inventory of the Bay's habitats, especially the Bay's unique and sensitive habitats that have been overlooked in past monitoring and inventory including intertidal, kelp bed, short bank, Torrance Beach, and artificial reefs. It also provides necessary baseline for the valuation (and potential damage assessment) of the Bay's habitats, for special designation (e.g. ecological reserve) of certain areas, and for planning measures against abuse and depletion by pollution, development, or excessive harvesting. Additionally, it helps to identify the "habitats of concern" or "species of concern" and identify cost-effective methods for restoration and rebuilding efforts. It is anticipated that the initial mapping and inventory efforts planned by the SMBRP will identify many data gaps that need to be filled by special studies that:

- quantify the amount of substrate in the Bay and the Southern California Bight capable of supporting kelp beds
- assess the conditions of kelp habitats in the vicinity of Malibu
- analyze trends in the abundance of target species such as sea stars, owl limpets, and sea grasses based on historical surveys

- analyze trends in community composition and diversity of intertidal habitats in the Bay
- survey the abundance of resident species in the Bay
- assess the population sustainability of key commercial and sportfishing species

These studies could qualify to receive grant funding such as Section 205(j), SRF, or Proposition 13.

There are also a number of ongoing volunteer monitoring efforts underway in the WMA. They include storm event sampling at over 30 Bay storm drains coordinated by the Santa Monica BayKeeper, gutter patrol monitoring in inland neighborhoods and monitoring of Malibu Lagoon and the lower Creek for water quality and biological parameters coordinated by Heal the Bay, water quality and biological monitoring and surveys of Malibu lagoon coordinated by the Resource Conservation District of the Santa Monica Mountains, monitoring of the upper Malibu Creek Watershed, and coliform monitoring of the surf zone off of Malibu coordinated by the Malibu Chapter of the Surfrider Foundation.

WETLANDS PROTECTION AND MANAGEMENT

The wetlands priority in the Ballona Creek Watershed is Ballona Wetlands. Currently, the restoration process is stalled due to controversy surrounding approval of a large development in the area. Previous planning efforts have produced a wetlands restoration plan known as a "hybrid" plan, which contains elements of both full and mid-tidal alternatives in a manner that reduces environmental impacts and minimizes costs. Depending on the development plan approval process, the strategy is to ensure that adequate funding sources are secured for implementation of the restoration plan. The Regional Board participated in this activity through the 401 water quality certification process.

In the Malibu area, <u>The Southern California Wetlands Recovery Project</u> considers the Malibu Lagoon Water Level Control Project a high priority for FY00/01 or future funding. Also considered a high priority for funding is the Upper Malibu Creek Feasibility Study which would join with US Army Corps to study the feasibility of removing Rindge Dam. Two other high priority projects in the Santa Monica WMA is the Topanga Lagoon Restoration Feasibility Study and Solstice Creek Steelhead Enhancement work.

<u>The Santa Monica Mountains Conservancy</u> is a state agency created by the Legislature in 1979 charged with primary responsibility for acquiring property with statewide and regional significance, and making those properties accessible to the general public. The Conservancy manages parkland in the Santa Monica Mountains, Santa Susana Mountains, the Simi Hills, the Santa Clarita Woodlands, the Whittier-Puente Hills, the Sierra Pelona, the Los Angeles River Greenway, the Rio Hondo, the Verdugo Mountains, the San Gabriel Mountains, and the San Rafael Hills. The agency's goals are to: 1) implement the Santa Monica Mountains Comprehensive Plan, 2) implement the Rim of the Valley Trails Corridor Master Plan, 3) implement the Los Angeles County River Master Plan, 4) further cooperation with local governments in the region to secure open space and parkland, and 5) expand education, public access, and resource stewardship components in a manner that best serves the public, protects habitat, and provides recreational opportunities.

NONPOINT SOURCE PROGRAM

Nonpoint source pollution to the ocean (greater Santa Monica Bay) includes urban runoff, aerial fallout, spills, sediment resuspension, oil seeps, vessel traffic, and advection. Strategies for dealing with urban and storm runoff were discussed under the Core Regulatory section. In addition, a priority over the next two years is to divert dry weather flows from all problematic storm drains to the sewer system. Currently, diversions of six storm drains (Pico-Kenter, Ashland, Brooks Ave., Herondo St., Pershing Dr., and Thornton Ave.) have been fully or partially funded through Proposition A money. Therefore, more attention will be shifted to deal with Santa Monica Canyon, the only problematic drain that has not been scheduled for diversion, and Santa Monica and Redondo Piers, where measures to prevent sewer system leakage may be needed.

Strategies have been developed and efforts are underway to address aerial fallout, sediment resuspension, septic systems, marinas, and vessel traffic.

Septic Systems: In January 2000, the Santa Monica Bay Restoration Project (SMBRP) convened a Task Force to address the issue of septic system management throughout the northern Santa Monica Bay watersheds. The area of focus covers three jurisdictions: the City of Malibu, the City of Los Angeles, and areas of unincorporated Los Angeles County. In order to bring together the various perspectives and expertise on this issue, the Task Force was composed of representatives from various stakeholder organizations including: State Department of Health Services (SDHS); Los Angeles Regional Water Quality Control Board (RWQCB); California Coastal Commission; Los Angeles County Departments of Public Works, Health Services and Regional Planning; City of Los Angeles Department of Building and Safety; City of Malibu Environmental and Building Safety Department; Los Angeles County Board of Supervisors Office - Third District; and Heal the Bay.

The Task Force's goal has been to develop solutions to the problems associated with septic systems and their impact on water quality, while at the same time identifying the obstacles that must be faced in trying to mitigate the situation. By bringing an understanding of these obstacles into the formulation of its recommendations, the Task Force has tried to ensure that the solutions are implementable and still fully address the problem at hand.

After its review of the existing management and regulatory framework for septic system management in the Bay's watersheds, the Task Force's recommendations suggest that improving management of septic systems will require significantly greater oversight by both state and local agencies as well as improved coordination between them.

The Task Force recommends a comprehensive approach to septics system management in northern Santa Monica Bay that includes the following elements:

- **Issue waste discharge requirements (WDRs) for all existing multi-family and commercial establishments in northern Santa Monica Bay watersheds.**
  - The RWQCB should issue WDRs for all existing commercial and applicable multi-unit developments in northern Santa Monica Bay watersheds that are not currently permitted. It is estimated that there are approximately 380 systems that need permits in this area.
  - Develop general WDRs for common types of commercial and multi-unit residential units to facilitate the permitting process.

- Seek funding to increase RWQCB staffing to reduce the permit backlog.

- **Establish a comprehensive permitting program for operation, inspection and monitoring of all septic systems.**
  - Local agencies should require operational permits for all (commercial, multi-unit and single-family) septic systems. These permits would be issued on a five-year renewal basis, with shorter intervals for poorly performing systems.
  - Develop a comprehensive inspection and monitoring program that would be implemented through the operational permits. Require that initial inspections be conducted between six and 12 months after installation of new systems.
  - All properties served by septic systems should be permitted within five years of the adoption of these recommendations by local municipalities.
  - Develop computerized management systems to track and analyze permits, maintenance and inspection schedules.

- **Design and implement a comprehensive groundwater monitoring program to improve assessments of septic system impacts to receiving waters and groundwaters.**
  - Design a regional groundwater monitoring program in order to obtain information needed to better understand groundwater conditions and reduce the number of monitoring wells that may be required of permittees. This monitoring program would be implemented through WDRs.

- **Establish a coordinated approach for oversight of septic systems, including modification/update of the WDR waivers between the RWQCB and local agencies.**
  - The RWQCB and local agencies should establish agreements that ensure consistent implementation of a policy that all commercial and multisystems obtain WDRs before building permits are issued by local agencies.

- **Develop a grants program for qualified homeowners to provide financial assistance to upgrade failing systems.**
  - Establish a financial assistance program for homeowners for which the upgrade, replacement or repair of failing on-site waste disposal systems would be a significant financial hardship.

- **Develop more stringent requirements for installation and operation of wastewater management systems in environmentally sensitive areas.**
  - Utilize a risk-based approach in implementing the operational permit program, e.g. identify environmentally sensitive areas to be addressed as high priority, develop more stringent operating permits for wastewater management systems in these areas.

- **Establish local septic system maintenance districts to oversee and fund the permitting, inspection and monitoring activities.**
  - The process for establishing such a district is outlined in the State Health and Safety Code.

- **Conduct public outreach to residents regarding proper operation and maintenance of septic systems.**
  - Educational outreach to septic system owners should be conducted regarding proper operation and maintenance of septic systems and regarding the implementation of the proposed permitting and inspection programs.

The Task Force is currently seeking approval and support of these recommendations from the agencies responsible for their implementation. Finalized recommendations will be incorporated into the Santa Monica Bay Restoration Plan with the ultimate goal of implementation by all appropriate entities.

Aerial Fallout: Funded by USEPA, the SMBRP will conduct a study of air transport/deposition of toxic contaminants to the Bay over the next three years. This study will quantify the toxic materials and nitrogens emitted annually in the Los Angeles air basin that are subsequently deposited in the Bay and the Bay's watershed, and identify the sources of various airborne pollutants in the air basin and their relative contributions to total pollutant loading to the Bay. The Regional Board has been assisting the SMBRP by encouraging participation of the stormwater management agencies. The Regional Board can use this information to evaluate the effectiveness of air pollution control measures.

Sediment Resuspension: Currently, there is no study specifically planned to examine sediment resuspension as a source of pollutant loading to the Bay. However, the USEPA Superfund investigation on the Palos Verdes Shelf and the Contaminated Sediment Task Force are both looking into the sediment resuspension issue in order to evaluate the feasibility of capping as a remediation measure. USEPA initiated a pilot project in September 2000 to evaluate cap placement methods and cap stability at three test cells on the Palos Verdes Shelf. These two efforts will provide valuable information that will help evaluate relative contributions of pollutant loading from sediment resuspension.

Marinas and Vessel Traffic: Boating wastes (vessel traffic) are potentially a significant source of loadings into the Bay as well as into harbors of pathogens, trash, and some heavy metals. The SMBRP has organized a comprehensive boater education program for the southern California counties. In addition, the new Clean Marina 319h grant will further help educate boaters, facilitate clean-out practices, and promote recognition of successes.

Other NPS Activities: We will continue to manage a 319(h) project involving restoration of Zuma Lagoon. The goals of the project are: enhancement of existing native habitats, an increase in habitat diversity and expansion of freshwater marsh and willow riparian habitats through the use of native plantings, establishment of a sycamore alluvial woodland/coastal scrub habitat, and development of an interpretive area and trails that would serve to educate the public regarding the biological and cultural resources of the site. This project is projected to be finished by 2001.

A number of nonpoint source control strategies are being undertaken in the Malibu Creek Watershed. Those that involve restoration of contact and noncontact recreation beneficial uses include:

- An assessment of nutrient and bacteria inflow from septic systems adjacent to the Lagoon through the use of tracers, by the City of Malibu (a 205(j)-funded study).
- Development of a policy at the Regional Board to regulate/permit, if appropriate, septic systems in localized areas of Malibu and the Santa Monica Mountains area including Malibou Lake.
- Implementation of the waiver policy

Also, the City of Calabasas is using 319(h) money to develop and coordinate a watershed education center and library with a projected completion date of 2000.

We continue to support as a high priority for 319(h) program funding in FY2000/01 projects to restore wetlands in Malibu, Topanga, and Trancas Lagoons.

We anticipate a number of applicants will be pursuing Proposition 13 funding for implementation or restoration projects, particularly in the Malibu area.

Additionally, work will continue with the Bay Watershed Council, the Implementation Committees for Ballona Creek and Malibu Creek, with the Storm Water Santa Monica Bay Watershed Committees, and with other Santa Monica Bay Watershed stakeholder groups, in order to identify any necessary modifications and/or new nonpoint measures that should be implemented through the Bay Restoration Plan or individual Ballona Creek and Malibu Creek Plans.

BASIN PLANNING

As we are limited in resources and time to accomplish every watershed goal during the permit phase of the first cycle, the priority issues identified for the first cycle will need to be addressed during the remainder of the first cycle. We will continue to develop strategies for the implementation of priority actions identified under the Santa Monica Bay Restoration Plan, including protection of the Ballona Wetlands, as well as additional actions targeted by the Watershed Council for action. We will also integrate these into the Watershed Council's Plan and implementation activities.

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

Since most of the NPDES permits for this watershed were renewed in 1997, in general, core regulatory activities during the next four years will focus on permit compliance, monitoring report review, and enforcement as needed. Work continues on lower Malibu Creek issues. Members of the watershed team will be involved with periodic updates of the State of the Watershed Report. Additionally, there will be on-going interaction with stakeholders and followup on goals established during the permit renewal phase.

In particular, over the next two fiscal years, a number of issues need to be addressed that require additional funding. The major NPDES permits that were not renewed in 1997 (one POTW and the three generating stations) expired in 1999 (Scattergood, El Segundo and Redondo were renewed in 2000). The next watershed cycle when the Santa Monica Bay WMA will be targeted is in 2003/04. In the meantime, the POTW has completed construction of its secondary treatment facilities in order to achieve compliance with full secondary treatment requirements. There is a need to revise the facility's effluent monitoring program to include intermediate monitoring to determine removal efficiencies. There are also a number of major studies requested of dischargers have been submitted, are due soon, or are likely to take place which will require review and evaluation. Consolidation of non-storm water discharges into general permits specific to watersheds and development of a waiver program for de minimis non-storm water discharges also requires resources. **It is estimated the above activities will require an additional 2 PYs/year over baseline resources.**

Regarding resources needed to continue oversight of the Los Angeles County storm water permit (regulatory-based BMP management), regulatory personnel will be revising the annual program report format, auditing the permittees, evaluating the revised model programs, and reviewing reports and alternate programs submitted by permittees. The eighteen municipal program audits must be completed and matched with BMPs selected to address the pollutants of concern to facilitate development of TMDLs. The Caltrans storm water management program BMPs must be matched with pollutants of concern to facilitate TMDLs impacted by transportation land use. In addition, SWPPPs for all industrial storm water facilities in the WMA must be reviewed and BMPs matched with pollutants of concern to facilitate TMDL development. **These above activities will also require an additional 2 PYs.**

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

Issuing waste discharge requirements for all existing multi-family and commercial establishments in northern Santa Monica Bay watersheds not currently under permit (with any necessary followup work), as recommended by the Santa Monica Bay Restoration Project septic systems task force, will entail requiring **an additional 2 – 4 PYs per year for at least the next five years.**

There are a number of information gaps that need to be filled over the next few years such as:

- Review existing data and assess fish contamination levels in the entire Santa Monica Bay (not just the Palos Verdes Shelf).

- Analyze the link between contaminants in fish and biological impacts to shore birds, sea birds, and marine mammals.

- Continued involvement in updates to the baseline State of the Watershed Report, focussing on filling data gaps and evaluating cumulative impacts as monitoring data become available from dischargers.

- Regional Board ambient monitoring, and evaluation of monitoring data from the municipal storm water program.

- An important issue to address at some point in the future is the need to protect the populations of threatened and endangered species in the Bay which include the California least tern, Belding's savannah sparrow, western snowy plover, California brown pelican, El Segundo blue butterfly, steelhead trout, and tidewater goby. Depending on the level of existing efforts, the needs for each species range from monitoring and assessing current conditions, to developing or implementing strategies for population recovery.

- In the Malibu Creek Watershed, a number of long-term projects are being considered or are in progress which the Regional Board will be involved with to some extent. The Malibu Creek Watershed Council is projected to complete work on a Watershed Management Plan by 2001. This Plan would include implementation strategies to resolve concerns and issues in the watershed. The Department of Parks and Recreation and the City of Malibu are investigating development of a plan to reduce unseasonal breaching of the lagoon; a plan may be available by 2002. Also, the Rindge Dam Task Force is investigating the possibility and alternative ways to remove the dam in order to facilitate access to the upper watershed by steelhead trout. There is no projected end date for this project.

Additionally, although not a nonpoint source project per se, the POTW which discharges to Malibu Creek is under a discharge prohibition starting each May 1, or at the first natural closure of Malibu Lagoon by sand buildup (whichever is later), through and including October 31 of each year, except during times of plant upset, storm events, or the existence of minimal streamflow conditions that require flow augmentation in Malibu Creek to sustain endangered species. However, in the long-run, this discharge prohibition may have many other implications on water quality and quantity in the Creek and Lagoon.

- Develop a strategy for regulating septic systems in the Malibu area.
- A priority planning issue is to define water quality standards for nutrients in Malibu Lagoon and Creek.
- We will also continue our involvement with stakeholder activities and the pursuit of funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j), SRF, Prop. 13, Small Community Grant, and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.
- We plan on pursuing funding in FY00/01 in order to complete a nutrient TMDL in the Malibu Creek Watershed as well as start a coliform TMDL there. We also require funding for trash and coliform TMDLs in Ballona Creek and coliform TMDL in Marina del Rey Harbor.
- Comments on watershed issues in CEQA documents (for the highest priority projects) will continue to be prepared; however, there is currently no funding for this program.
- Implement biological monitoring in priority watersheds (e.g. Malibu, Topanga).

Potential Long-term Activities

In the long-term, Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

A wetlands management issue that will continue to impact core regulatory activities in Malibu Creek is the listing of the creek as critical habitat for the endangered steelhead trout. Water quantity will continue to play as critical a role as water quality in the issue.

We will continue to develop strategies for the implementation of priority actions identified under the Santa Monica Bay Restoration Plan, including protection of the Ballona Wetlands, as well as additional actions targeted by the Watershed Council for action. We will also integrate these into the Watershed Council's Plan and implementation activities. Additional issues may include: 1) conduct or review studies to evaluate and refine (if necessary) the designated beneficial uses for certain waterbodies, 2) consider the establishment of wet weather criteria in some areas, 3) integrate water supply and quality issues with local land use planning and management, and 4) institute better coordination of multi-agency reviews of environmental impacts for flood control and development projects, including the consideration of regional mitigation programs.

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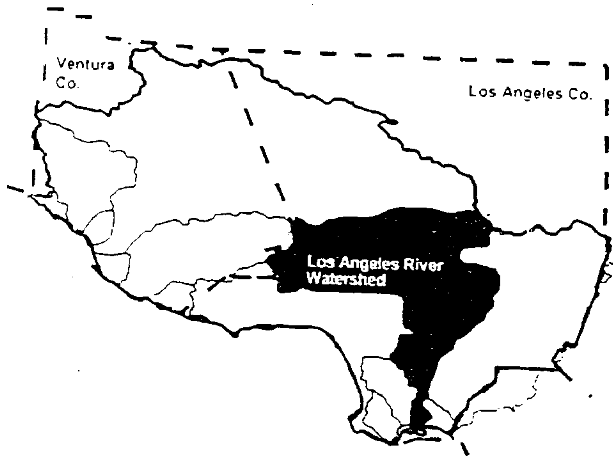
2.5 *LOS ANGELES RIVER WATERSHED*

This was the targeted watershed for permitting purposes in FY1997/99 and will be targeted again in FY 2004/05.

Overview of Watershed



Size of watershed: 824 square miles

Length of river: 55 miles

The Los Angeles (LA) River watershed is one of the largest in the Region. It is also one of the most diverse in terms of land use patterns. Approximately 324 square miles of the watershed are covered by forest or open space land including the area near the headwaters which originate in the Santa Monica, Santa Susana, and San Gabriel Mountains. The rest of the watershed is highly developed. The river flows through the San Fernando Valley past heavily developed residential and commercial areas. From the Arroyo Seco, north of downtown Los Angeles, to the confluence with the Rio Hondo, the river flows through industrial and commercial areas and is bordered by railyards, freeways, and major commercial and government buildings. From the Rio Hondo to the Pacific Ocean, the river flows through industrial, residential, and commercial areas, including major refineries and petroleum products storage facilities, major freeways, rail lines, and rail yards serving the Ports of Los Angeles and Long Beach.

Major tributaries to the river in the San Fernando Valley are the Pacoima Wash, Tujunga Wash (both drain portions of the Angeles National Forest in the San Gabriel Mountains), Burbank Western Channel and Verdugo Wash (both drain the Verdugo Mountains). Due to major flood events at the beginning of the century, by the 1950's most of the river was lined with concrete. In the San Fernando Valley, there is a section of the river with a soft bottom at the Sepulveda Flood Control Basin. The Basin is a 2,150-acre open space upstream of the Sepulveda Dam designed to collect flood waters during major storms. Because the area is periodically inundated, it remains in a semi-natural condition and supports a variety of low-intensity uses as well as supplying habitat. At the eastern end of the San Fernando Valley, the river bends around the Hollywood Hills and flows through Griffith and Elysian Parks, in an area known as the Glendale Narrows. Since the water table was too high to allow laying of concrete, the river in this area has a rocky, unlined bottom with concrete-lined or rip-rap sides. This stretch of the river is fed by natural springs and supports stands of willows, sycamores, and cottonwoods. The many trails and paths along the river in this area are heavily used by the public for hiking, horseback riding, and bird watching.

South of the Glendale Narrows, the river is contained in a concrete-lined channel down to Willow Street in Long Beach. The main tributaries to the river in this stretch are the Arroyo Seco (which drains areas of Pasadena and portions of the Angeles National Forest in the San

Gabriel Mountains), the Rio Hondo, and Compton Creek. Compton Creek supports a wetland habitat just before its confluence with the Los Angeles River. The river is hydraulically connected to the San Gabriel River Watershed by the Rio Hondo through the Whittier Narrows Reservoir. Flows from the San Gabriel River and Rio Hondo merge at this reservoir during larger flood events, thus flows from the San Gabriel River Watershed may impact the LA River. Most of the water in the Rio Hondo is used for groundwater recharge during dry weather seasons. The San Gabriel River drains approximately 689 square miles, which includes the eastern San Gabriel Mountains and portions of the Chino, San Jose, and Puente Hills.

Beneficial Uses in watershed:

Estuary	*Above estuary*
Industrial service supply	Groundwater recharge
Contact & noncontact water recreation	Contact & noncontact water recreation
Navigation	Warmwater habitat
Commercial & sportfishing	Wetlands Habitat
Protection of rare & endangered species	Protection of rare & endangered species
Wildlife habitat	Wildlife habitat
Marine habitat	
Migration of aquatic organisms	
Spawning	
Estuarine habitat	

The LA River tidal prism/estuary begins in Long Beach at Willow Street and runs approximately three miles before joining with Queensway Bay located between the Port of Long Beach and the city of Long Beach. The channel has a soft bottom in this reach with concrete-lined sides. Queensway Bay is heavily water recreation-oriented; however, major pollutant inputs are likely more related to flows from the LA River which carries the largest storm flow of any river in southern California.

Also part of the watershed are a number of lakes including Peck Road Park, Belvedere Park, Hollenbeck Park, Lincoln Park, and Echo Park Lakes as well as Lake Calabasas. These lakes are heavily used for recreational purposes.

Four basins in the San Fernando Valley area contain substantial deep groundwater reserves and are recharged mainly through runoff and infiltration although the increase in impermeable surfaces has decreased infiltration. Groundwater basins in the San Gabriel Valley are not separated into distinct aquifers other than near the Whittier Narrows. Active recharge occurs in some of these areas through facilities operated by Los Angeles County. Spreading grounds recharge two basins in the coastal plain of Los Angeles west of the downtown area.

Permitted discharges:

- Six major NPDES dischargers (four POTWs)
- 30 minor permits
- 112 dischargers covered by general permits
- Minor permits cover miscellaneous wastes such as ground water dewatering, recreational lake overflow, swimming pool wastes, and ground water seepage. Other permits are for discharge of treated contaminated ground water, noncontact cooling water, and storm water
- Two municipal storm water permits
- 1,327 dischargers covered under an industrial storm water permit
- 147 dischargers covered under a construction storm water permit

Water Quality Problems and Issues

Pollutants from dense clusters of residential, industrial, and other urban activities have impaired water quality in the middle and lower watershed. Added to this complex mixture of pollutant sources (in particular, pollutants associated with urban and stormwater runoff), is the high number of point source permits.

Types of permitted wastes discharged into the Los Angeles River Watershed:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	2 9	Minor General
Nonhazardous (designated) contact cooling water	1	Minor
Nonhazardous (designated) domestic sewage & industrial waste	3	Major
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	1 8 58	Major Minor General
Nonhazardous (designated) noncontact cooling water	3 13	Minor General
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	2	Minor
Nonhazardous (designated) stormwater runoff	1 9 1	Major Minor General
Hazardous contaminated groundwater	2 9	Minor General
Nonhazardous (designated) domestic sewage	1 1	Major Minor
Nonhazardous (designated) filter backwash brine waters	2	Minor
Nonhazardous wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	2	General
Inert contaminated groundwater	1	General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	16	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

A majority of the 148 NPDES discharges go directly to the Los Angeles River. Burbank Western Channel receives four discharges, Compton Creek receives five, and Eaton Wash receives three.

Of the 1,327 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Fabricated Metal Products, Except Machinery and Transportation Equipment*; *Motor Freight Transportation and Warehousing*; *Scrap and Waste Materials*; *Motor Vehicle Parts, Used*; *Primary Metal Industries*; and *Chemicals and Allied Products* categories.

There are a total of 147 construction sites enrolled under the construction storm water permit. About twice as many of these are in the upper watershed (which includes the San Fernando Valley) and the construction in this watershed is fairly evenly divided between commercial and residential.

IMPAIRMENTS: The majority of the LA River Watershed is considered impaired due to a variety of point and nonpoint sources. The 1998 303(d) list implicates pH, ammonia, a number of metals, coliform, trash, scum, algae, oil, chlorpyrifos as well as other pesticides, and volatile organics in that impairment. Some of these constituents are of concern throughout the length of the river while others are of concern only in certain reaches (see chart below). Impairment may be due to water column exceedances, excessive sediment levels of pollutants, or bioaccumulation of pollutants. The beneficial uses threatened or impaired by degraded water quality are aquatic life, recreation, groundwater recharge, and municipal water supply.

The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3 - 28.0 mg/l to protect against acute toxicity	ND - 34.9 mg/l (mean of 10.7 ± 4.8)	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reach 5 (within Sepulveda Basin) Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Burbank Western Channel Rio Hondo Reach 2 (from Whittier Narrows Flood Cntrl Basin to Spreading Grounds) Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Lincoln Park Lake Echo Park Lake Lake Calabasas
nutrients (algae)	Basin Plan narrative objective Basin Plan numeric objective: nitrates-N + nitrites-N not greater than 10 mg/l	0.2 - 14.5 mg/l (mean of 2.7 ± 3.2)	Los Angeles River Reach 5 (within Sepulveda Basin) Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Burbank Western Channel Verdugo Wash (Reaches 1 & 2) Arroyo Seco Rch 1 (d/s Devil's Gate Dam) & Rch 2 (W. Holly Ave. to Devil's Gate) Lincoln Park Lake Echo Park Lake Lake Calabasas
Scum, odors	Basin Plan narrative objective		Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reach 5 (within Sepulveda Basin) Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Burbank Western Channel Peck Rd Lake Lincoln Park Lake Echo Park Lake Lake Calabasas
pH	Basin Plan numeric objective: 6.5 - 8.5 pH units	7.0 - 10.6 pH units (mean of 9.2 ± 0.9)	Los Angeles River Reach 1(u/s Carson St. to estuary) Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Compton Creek Echo Park Lake Lake Calabasas

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Low DO/organic Enrichment	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	0.2 - 15.2 mg/l (mean of 6.0 ± 4.0)	Lincoln Park Lake Peck Rd Lake Lake Calabasas
Trash	Basin Plan narrative objective		Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reach 5 (within Sepulveda Basin) Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Burbank Western Channel Verdugo Wash (Reaches 1 & 2) Arroyo Seco Reach 1 (d/s Devil's Gate Dam) & Reach 2 (W. Holly Ave. to Devil's Gate) Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Peck Rd Lake Echo Park Lake Lincoln Park Lake
Copper	USEPA water quality criteria: varies based on hardness but typically 12 - 47 ug/l	63 ug/l (maximum)	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Compton Creek Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Echo Park Lake Lake Calabasas
Lead	USEPA water quality criteria: varies based on hardness but typically 3.2 - 25 ug/l	140 ug/l (maximum)	Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Monrovia Cyn Creek Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Compton Creek Peck Rd Lake Lincoln Park Lake Echo Park Lake
Cadmium	USEPA water quality criteria: varies based on hardness but typically 1.1 - 4.0 ug/l	3 ug/l (maximum)	Burbank Western Channel
Zinc	USEPA water quality criteria: varies based on hardness but typically 106 - 414 ug/l	1,340 ug/l (maximum)	Lake Calabasas Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)
Selenium	USEPA water quality criteria: 5.0 ug/l	9.3 ug/l (maximum)	Aliso Canyon Wash
coliform	Basin Plan numeric objective: Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	ND - 93,000 MPN/100ml	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reach 6 (u/s of Sepulveda Basin) Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.) Los Angeles River Reach 1(u/s Carson St. to estuary) Verdugo Wash (Reaches 1 & 2) Arroyo Seco Rch 1 (d/s Devil's Gate Dam) & Rch 2 (W. Holly Ave. to Devil's Gate) Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River) Rio Hondo Reach 2 (Whittier Narrows Flood Control Basin to Spreading Grounds) Compton Creek Bell Creek
chlorpyrifos	Basin Plan narrative objective		Los Angeles River Reach 5 (within Sepulveda Basin)
Chem A*	National Academy of Science Guideline (tissue): 100 ng/g		Los Angeles River Reach 5 (within Sepulveda Basin)
PCBs	State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g		Echo Park Lake
DDT	State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g		Peck Rd Lake Lake Calabasas
chlordane	State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g		Peck Rd Lake

* Chem A refers to the sum of the chemicals aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, HCH (including lindane), endosulfan, and toxaphene

Potential sources of pollution:

- POTWs
- Industrial discharges
- septic systems
- landfills
- Nonpoint sources (horse stables, golf courses)
- Illegal trash dumping
- Cross-contamination between surface and groundwater

Ground water resources in the watershed are also impacted. Impacts, both real and threatened, include those from hundreds of cases of known leaking underground storage tanks that have contaminated soil and/or ground water with petroleum hydrocarbons and volatile organic compounds. There are also a number of cases of refineries/tank farms that have contaminated soil and/or ground water. Seawater intrusion (chloride) is of concern in other areas of the watershed which has necessitated wellhead treatment, shutdown, or blending. Finally, a number of wells have been shut down due to nitrate contamination with septic systems as a likely source.

ISSUES: The major issues of concern in the watershed include: 1) protection and enhancement of fish and wildlife habitat, 2) removal of exotic vegetation, 3) enhancement of recreational areas, 4) attaining a balance between water reclamation and minimum flows to support habitat, 5) management of storm water quality, 6) assessment of other nonpoint sources including horse stables, golf courses, and septic systems, 7) pollution from contaminated ground water, 8) groundwater recharge with reclaimed water, 9) contamination of ground water by volatile organic compounds, 10) leakage of MTBE from underground storage tanks, 11) groundwater contamination with heavy metals, particularly hexavalent chromium, and 12) contaminated sediments within the LA River estuary.. Some of these issues are only indirectly related to water quality but are those identified by stakeholder groups.

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
trash	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reaches 1, 2, 3, 4, 5 Burbank Western Channel Verdugo Wash Reaches 1 & 2 Arroyo Seco Reaches 1 and 2 Rio Hondo Reach 1	00/01
nitrogen and related effects	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Los Angeles River Reaches 1, 2, 3, 4, 5 Burbank Western Channel Verdugo Wash Reaches 1 & 2 Arroyo Seco Reaches 1 and 2 Rio Hondo Reaches 1 and 2 Compton Creek	01/02
coliform	Los Angeles River Reaches 1, 2, 4, and 6 Tujunga Wash (d/s Hansen Dam to LA River) Verdugo Wash Reaches 1 and 2 Arroyo Seco Reach 1 Rio Hondo Reaches 1 and 2 Compton Creek	01/02

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
metals	Tujunga Wash (d/s Hansen Dam to Los Angeles River) Compton Creek Burbank Western Channel Los Angeles River Reaches 1, 2, 4 Rio Hondo Reach 1 Monrovia Cyn Creek Aliso Canyon Wash	03/04
hist. pesticides	Los Angeles River Reach 5 (within Sepulveda Basin)	05/06

We see a need for an additional 1.9 PYs and $100,000 of contract monies for FY00/01 TMDL work conducted in this watershed.

Stakeholder Groups

Los Angeles/San Gabriel Rivers Watershed Council The group was formed in 1995 following a large watershed conference held in the area which served as a springboard. The Council has a board of directors and became incorporated as a nonprofit organization in 1996. The group is tracking watershed activities, but has primarily focused on flood control issues in the Los Angeles River as well as opportunities to create greenbelts and restore habitat. Three committees have been formed recently: water resources, water quality, and multi-use projects. The Council's goal is to help facilitate a process to preserve, restore, and enhance all aspects of the two watersheds. Preparation of a watershed management plan by this group is underway. This group is coordinating with other groups to seek Proposition 13 funding. Generally one staff person attends these monthly council as well as monthly board of directors meetings. More information about this group may be found at their website http://www.lasgriverswatershed.org/.

Los Angeles Basin Contaminated Sediment Task Force Contaminated dredged material disposal is a major issue in the Los Angeles Region due to its large commercial ports and the several major marina complexes and small vessel harbors. .Queensway Bay, at the mouth of the watershed, receives a large sediment load that impacts recreational uses. The U.S. Army Corps of Engineers frequently conducts maintenance dredging to remove accumulated sediments from this area. The need for a long-term management strategy for dealing with contaminated sediments in the Los Angeles area has been identified and the Task Force will prepare this strategy. Representatives on the Task Force include a number of federal and state agencies as well as port and environmental group representatives. More information about this group may be found in the Region-wide Section of this Chapter.

Past Significant Activities

CORE REGULATORY

The Los Angeles County Storm Water Permit (which the LA River Watershed falls within) permit was renewed in July 1996.

WATERSHED MANAGEMENT

Key regulatory staff are part of a LA River Watershed "team" for purposes of preparing a State of the Watershed Report/Water Quality Characterization Report (a draft of which was released April 13, 1998) and for coordinating permit renewals and regional monitoring program development.

Current Activities

The following is a summary of current Regional Board activities in the Los Angeles River Watershed which are expected to continue as part of the Watershed Management Initiative on a watershed basis. Activities which address the aforementioned pollutants or issues of concern are highlighted. Additionally, there are a large number of projects and activities currently underway by watershed stakeholders ranging from a wetlands assessment funded by the Coastal Conservancy and others to an NPDES Permit Public Education Program funded by the City of Alhambra.

CORE REGULATORY

Continuing core regulatory activities that have been integrated into the watershed management approach include (but are not limited to) renewal/revision of NPDES permits including those covered under Regional Board general permits. Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue. A draft watershed-wide regional monitoring program was created in 1998/99 and our modifications and improvements to discharger monitoring programs will target data gaps and eliminate duplicative and unnecessary monitoring. Coordination between major dischargers, environmental groups, volunteer monitors, and resource and regulatory agencies will be critical to the success of this task. Because of the large number of permits, renewal of permits in this watershed during its first cycle was spread over two years.

The Los Angeles River Watershed falls within Los Angeles County which was issued a renewed municipal storm water permit in 1996. There are 87 co-permittees covered under this permit including 85 cities, the County of Los Angeles, and the California Department of Transportation (Caltrans). Work on the permit will involve review of monitoring reports, evaluation of the storm water program's effectiveness, coordination with other watershed efforts, and modification of the permit as necessary. During 1997/98, discharger responsibilities under the permit concentrated on the evaluation of the five BMP model programs required in the 1996 permit: Illicit Connection/Illicit Discharges, Development Construction, Development Planning, Public Agency Activities, and Five-Year Public Education Strategy (including industrial/commercial site visits). The watershed also falls partly within the City of Long Beach which was issued a municipal storm water permit in 1999.

An important requirement of both storm water municipal permits is implementation of the Standard Urban Storm Water Mitigation Plans (SUSMPs) and Numerical Design Standards for Best Management Practices (BMPs) which were adopted in 2000. The SUSMP is designed to ensure that storm water pollution is addressed in one of the most effective ways possible, i.e., by incorporating BMPs in the design phase of new development and redevelopment. It provides for numerical design standards to ensure that storm water runoff is managed for water quality concerns in addition to flood protection and that pollutants carried by storm water are retained and not delivered to waterways.

The numerical design standard is that post-construction treatment BMPs be designed to mitigate (infiltrate or treat) storm water runoff from the first ¾ inch of rainfall, prior to its discharge to a storm water conveyance system. Other standards also apply; additional information on the SUSMP may be found on the Regional Board website http://www.swrcb.ca.gov/~rwqcb4.

Regulation of groundwater protection activities is intended to eventually become integrated into the watershed management approach while land disposal activities will likely remain separate. Accomplishment of core regulatory activities are a high priority that is currently funded; however, funds do not tend to go far enough to encompass extensive enforcement and response to complaints; however, enforcement is a high priority.

Due to limited resources, only the basic regulatory activities are performed: review of dischargers' monitoring reports, minimum necessary inspections and sampling, issuance/renewal of permits, levels 1 and 2 enforcement actions (noncompliance and violation notification), case handling, and answering inquiries from the public.

MONITORING AND ASSESSMENT

Work on a TMDL for nitrogen in the watershed is currently underway. A preliminary draft was released to the public on April 1, 1998; however, due to staff changes and resources, it was not completed. A public draft of this TMDL is expected to be available early in the summer of 2001.

A State of the Watershed/Water Quality Characterization Report was prepared during 1997/98 based on information obtained through the Board's ambient monitoring program, dischargers' receiving water monitoring data, and data available from other agencies. The first edition of the report focuses on the upper LA River Watershed. This document was released in April 1998.

NONPOINT SOURCE PROGRAM

The major nonpoint source-generated pollutants found throughout the watershed that have contributed to its impairments are lead, coliform, and oil, while chlorpyrifos is implicated in the upper watershed. These pollutants are common components of dry weather urban runoff and wet weather storm runoff. In many ways, the "point source" municipal stormwater permit for LA County will be a major tool in nonpoint source pollution elimination. Permitees are responsible for development and implementation of storm water management plans, for plans to eliminate non-storm water discharges (dry weather urban runoff), and must apply best management practices to prevent storm water pollution.

The Regional Board encourages pollution prevention and source control; the 205(j) and 319(h) grants are tools to provide funds for these types of projects. For FY00/01, we have listed as a priority for 319(h) grant funding activities (see Table 4) which demonstrate effective ways to reduce loadings of trash, nutrients, and coliform through pilot projects which implement trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, or implementation of septic correction measures.

Staff will also be involved in stakeholder meetings and will assist in the development of watershed management plans which will be expected to address strategies to reduce point and nonpoint source pollutants as well as other issues other than strictly water quality concerns. A strong stakeholder group already exists and has been meeting regularly.

BASIN PLANNING

A priority basin planning issue is to implement the Basin Plan's ammonia objective. Some dischargers believe the objective may be too stringent for certain waters and that site-specific objectives may be justified while some resource agencies and many environmental groups support the current objective. The regional board objective for ammonia allows for studies to be performed to explore site-specific objectives, if appropriate. Dischargers which must meet this objective by June 2002, and should be well on their way to compliance by this point. This issue is especially relevant in the LA River since ammonia is already known to be a pollutant of concern.

Determination of appropriate nutrient (nitrate and phosphate) objectives for protection of aquatic life is also a remaining issue.

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

Review and comment on EIRs for the highest priority projects within the watershed will continue; however, there is currently no funding for this program.

WETLANDS PROTECTION AND MANAGEMENT

The San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy is an independent State agency within the Resources Agency. State law established the Conservancy in 1999. Its jurisdiction includes the San Gabriel River and its tributaries, the Lower Los Angeles River and its tributaries, and the San Gabriel Mountains. Puente Hills, and San Jose Hills. It was established to preserve open space and habitats in order to provide for low-impact recreation and educational uses, wildlife and habitat restoration and protection, and watershed improvements within its jurisdiction. It is currently involved with beginning work on an open space plan for the area. Propositions 12 and 13 have directed funds to the Conservancy. The Santa Monica Mountains Conservancy is a state agency created by the Legislature in 1979 charged with primary responsibility for acquiring property with statewide and regional significance, and making those properties accessible to the general public. The Conservancy manages parkland in the Santa Monica Mountains, Santa Susana Mountains, the Simi Hills, the Santa Clarita Woodlands, the Whittier-Puente Hills, the Sierra Pelona, the Los Angeles River Greenway, the Rio Hondo, the Verdugo Mountains, the San Gabriel Mountains, and the San Rafael Hills. The agency's goals are to: 1) implement the Santa Monica Mountains Comprehensive Plan, 2) implement the Rim of the Valley Trails Corridor Master Plan, 3) implement the Los Angeles County River Master Plan, 4) further cooperation with local governments in the region to secure open space and parkland, and 5) expand education, public access, and resource stewardship components in a manner that best serves the public, protects habitat, and provides recreational opportunities.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

Following renewal of the watershed's permits, core regulatory activities will focus on permit compliance, monitoring report review, and enforcement as needed. Members of the watershed team will be involved with periodic updates of the State of the Watershed Report. Additionally, there will be on-going interaction with stakeholders and followup on goals established during the permit renewal phase. Pending completion of a final TMDL we will pursue agreement on pollutant loadings that can be implemented through future NPDES permits, the municipal stormwater permit, and through other nonpoint source control measures.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

We are making significant progress toward identifying and assessing problems in the upper watershed and involving stakeholders. Also by this time, we shall have completed intensive sampling and modeling of ammonia loads in the main channels in the Los Angeles River watershed for a TMDL which will give us a headstart on assessing and allocating pollutant loadings from both point and nonpoint sources.

Monitoring and special studies: Quarterly water quality assessment monitoring at a minimum of 14 stations along the LA River Watershed (particularly its tributaries) with sampling for general minerals, nutrients, metals, coliform, pesticides, radioactivity, volatile organics, and other organics, as well as gathering baseline information on trash, is proposed. **The annual cost of this monitoring is estimated at $113,400.** This monitoring will be in addition to monitoring of the main channel conducted by dischargers. **Additionally, a number of special studies will be needed which are expected to cost a total of $108,000.** TMDLs that need to be developed include:

1) Ammonia: The first phase of the TMDL was completed in FY97/98. Currently the model is at the calibration stages for dry weather simulations. Historical data as been gathered from the Regional Board and various other agencies to calibrate the model. Wet season calibration for the model will occur in the first quarter of 2001. Sampling efforts are currently underway to gather data for the wet season calibration effort. Investigation of nitrogen uptake by algae and algal growth rates and river nitrification rates are currently underway, and will be available for use in the model simulations.

2) Coliform: A first review indicates that the coliform contributions from POTWs is not significant. To give us a rough estimate of the sources of coliform, special studies are needed to determine the type of coliform present in the river: from human waste, horses, wildlife, or other. **These studies are estimated to cost $75,000.** Once the sources have been identified, a load allocation may be calculated, and BMPs or other solutions may be proposed to achieve such allocations.

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3) Metals: To develop a first phase TMDL for metals, more monitoring is needed. However, staff resources should be dedicated to data assessment and analysis, and to prepare an implementation strategy.

4) Trash: The municipal stormwater permit co-permittees in coordination with the Regional Board will be conducting a study to determine the threshold level for beneficial use impairment as part of this TMDL effort. A draft TMDL is out for review and is scheduled for adoption at a January 25, 2000, Board meeting.

5) Pesticides: A section of the river has been listed impaired due to pesticides found in fish or shellfish. POTWs are currently implementing effluent limitations to control pesticide loadings. Nonpoint source contributions need to be estimated. If toxicity money is available, **$100,000 would allow us to pinpoint specific areas and seasons where we have problems.**

6) Volatile organic compounds: A section of the river has been listed impaired due to VOCs from ground water. As efforts to clean up the ground water in the San Fernando Valley are implemented, staff expects that contamination from VOCs will decrease. Monitoring of VOCs is needed to determine if this assumption is correct.

Our efforts to involve stakeholders also shall include exploration of funding options (especially for implementation of nonpoint source measures) and continuation of other outreach activities, such as presentations, meetings, and participation in environmental events.

Also, efforts are underway to address problems with urban runoff (through the storm water municipal and industrial NPDES permits) and septic systems. Future activities should focus on horse corrals and golf courses, parks or other green areas. Activities proposed include outreach to implement BMPs. Tier I activities also should include monitoring and assessment to determine if Tier 2 or Tier 3 activities are needed to ensure successful implementation of BMPs and reduction of nitrogen and coliform loadings.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

Potential Long-term Activities

In the long-term, Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities (such as more refined regional procedures for conducting use attainability analyses and site-specific objective development) into the next update of the Basin Plan. More detailed analysis regarding certain beneficial uses needs to be done (species inhabiting/using the river, potential for aquatic life in the river, future water supply needs/diversions, ground water recharge areas). We will continue to pursue funding for Basin Planning programs. Comments on watershed issues in CEQA documents (for the highest priority projects) will continue to be prepared; however, there is currently no funding for this program.

Other issues include:

- Balancing maintenance of habitat in the river with flood control needs
- Evaluation of areas in the river for restoration purposes
- Evaluating critical habitat areas
- Evaluating the most protective (while providing flood control) long-term plans for vegetation/sediment removal under the 401 certification program
- Evaluate and implement low flow diversions where appropriate
- Assist in greenway developments along the river
- Evaluate estuarine habitats and water quality
- Implementing biological monitoring

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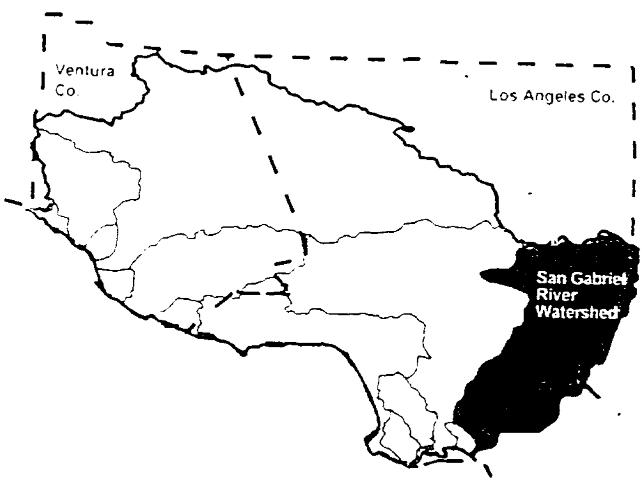
2.6 SAN GABRIEL RIVER WATERSHED

This watershed will be targeted for permit renewal purposes in FY05/06.

Overview of Watershed



Size of watershed: 689 sq. mi.

The San Gabriel River receives drainage from a large area of eastern Los Angeles County; its headwaters originate in the San Gabriel Mountains. The watershed consists of extensive areas of undisturbed riparian and woodland habitats in its upper reaches. Much of the watershed of the West Fork and East Fork of the river is set aside as a wilderness area; other areas in the upper watershed are subject to heavy recreational use. The upper watershed also contains a series of flood control dams. Further downstream, towards the middle of the watershed, are large spreading grounds utilized for groundwater recharge. The watershed is hydraulically connected to the Los Angeles River through the Whittier Narrows Reservoir (normally only during high storm flows). The lower part of the river flows through a concrete-lined channel in a heavily urbanized portion of the county before becoming an soft bottom channel once again near the ocean in the city of Long Beach. Large electrical power poles line the river along the channelized portion and nurseries, small stable areas, and a large poultry farm are located in these areas.

Beneficial Uses designated in the watershed:

Estuary	Above Estuary
Contact & noncontact water recreation	Contact & noncontact water recreation
Industrial service supply	Industrial service supply
Protection of rare & endangered species	Protection of rare & endangered species
Wildlife habitat	Wildlife habitat
Spawning	Spawning
Marine habitat	Warm- & coldwater habitat
Estuarine habitat	Municipal water supply
Navigation	Groundwater recharge
Commercial & sportfishing	Industrial process supply
Migratory	Agricultural supply

Water Quality Problems and Issues

Pollutants from dense clusters of residential and commercial activities have impaired water quality in the middle and lower watershed. Tertiary effluent from several sewage treatment plants enters the river in its middle reaches (which is partially channelized) while two power generating stations discharge cooling water into the river's estuary. The watershed is also covered under two municipal storm water NPDES permits. Several landfills are also located in the watershed.

Several reservoirs, which exist primarily for flood control purposes, occur in the upper part of the watershed. Frequent removal of accumulated sediments is necessary to maintain the flood control capacity of these reservoirs. Some of the removal methods previously used have had water quality impacts. Continued need for such maintenance could cause longer-term impacts. A study is currently underway to better assess impacts associated with the sluicing projects.

Significant Issues:

- Sluicing of reservoirs
- Protection of groundwater recharge areas
- Trash in upper watershed
- Mining/stream, modifications
- Ambient toxicity
- Urban and storm water runoff quality

Permitted discharges:

- Nine major NPDES dischargers (five POTWs)
- 23 minor permits
- 2 municipal storm water permits
- 65 discharges covered under general permits
- 549 dischargers covered under an industrial storm water permit
- 175 dischargers covered under a construction storm water permit

Types of permitted wastes discharged into the San Gabriel River Watershed:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	3	General
Nonhazardous (designated) contact cooling water	1 2	Major Minor
Nonhazardous (designated) domestic sewage & industrial waste	5	Major
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	4 37	Minor General
Nonhazardous (designated) noncontact cooling water	1 1	Minor General
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	1 2	Major Minor
Nonhazardous (designated) stormwater runoff	1 9 1	Major Minor General
Nonhazardous (designated) washwater waste (photo reuse washwater, vegetable washwater)	1	Minor
Hazardous contaminated groundwater	3 7	Minor General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage)	1 16	Minor General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

A majority of the 99 NPDES permittees in the watershed discharge directly to the San Gabriel River (38). Nineteen discharge to Coyote Creek and twelve discharge to San Jose Creek.

Of the 549 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Fabricated Metal Products, Except Machinery and Transportation Equipment*; *Chemicals and Allied Products*; *Motor Freight Transportation and Warehousing*; and *Motor Vehicle Parts, Used* categories.

There are 175 construction sites enrolled under the construction storm water permit. The sites are fairly evenly divided between residential and commercial and a similar number of sites are found in both the upper and lower watershed.

IMPAIRMENTS: The upper reaches of the river (in the Angeles National Forest) are heavily used for recreational purposes and have been impacted from trash, debris, and habitat destruction. Various reaches of the river are on the 1998 303(d) list due to nitrogen and its effects, trash, PCBs and pesticides, metals, and coliform. The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3-28.0 mg/l to protect against acute toxicity	ND - 21.1 mg/l (mean of 10.1±4.1)	San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) San Gabriel River Reach 1 (Estuary to Firestone) San Jose Creek Reach 2 (Temple to I-10 at White Ave) San Jose Creek Reach 1 (SG confluence to Temple St.) Coyote Creek Legg Lake El Dorado Lakes
toxicity	Basin Plan narrative objective	0 – 100% survival	San Gabriel River Reach 3 (Whittier Narrows to Ramona) San Gabriel River Reach 1 (Estuary to Firestone) Coyote Creek Walnut Creek
algae	Basin Plan narrative objective		San Gabriel River Reach 1 (Estuary to Firestone) San Jose Creek Reach 1 (SG confluence to Temple St.) San Jose Creek Reach 2 (Temple to I-10 at White Ave) Coyote Creek El Dorado Lakes
Eutrophication	Basin Plan narrative objective		El Dorado Lakes
pH	Basin Plan numeric objective: 6.5 - 8.5 pH units	6.9 - 9.4 pH units (mean of 8.5±0.6)	Walnut Creek El Dorado Lakes Legg Lake Santa Fe Dam Park Lake
odors	Basin Plan narrative objective		Legg Lake
low DO, organic enrichment	Basin Plan narrative objective Basin Plan numeric objective: annual mean greater than 7.0 mg/l no single sample less than 5.0 mg/l	0.1 - 14.9 mg/l (mean of 4.3±3.5)	Puddingstone Reservoir Crystal Lake
trash	Basin Plan narrative objective		San Gabriel River East Fork Legg Lake
Lead	USEPA water quality criteria: varies based on hardness but typically 3.2 - 25 ug/l	100 ug/l (maximum)	San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) Santa Fe Dam Park Lake El Dorado Lakes Legg Lake
Arsenic (tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 200 ng/g	240 - 300 ng/g (tissue)	San Gabriel River Estuary
Copper	USEPA water quality criteria varies based on hardness but typically 12 - 47 ug/l	90 ug/l (maximum)	Legg Lake El Dorado Lakes Santa Fe Dam Park Lake
Silver	USEPA water quality criteria varies based on hardness but typically 4.1 - 65 ug/l	30 ug/l (maximum)	Coyote Creek
Mercury (tissue)	NAS guidelines (tissue): 500 ng/g	510 ng/g (tissue)	Puddingstone Reservoir El Dorado Lakes

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
coliform	Basin Plan numeric objective: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml	ND - 240000 MPN/100ml	San Jose Creek Reach 2 (Temple to I-10 at White Ave) San Jose Creek Reach 1 (SG confluence to Temple St) San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam) San Gabriel River Reach 1 (Estuary to Firestone) Coyote Creek
DDT	State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	25 - 36 ng/g (tissue)	Puddingstone Reservoir
PCBs	State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	54 - 65 ng/g (tissue)	Puddingstone Reservoir
chlordane	State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	16.1 - 31.7 ng/g (tissue)	Puddingstone Reservoir
abnormal fish histology	Basin Plan narrative objective		Coyote Creek San Gabriel River Reach 1 (Estuary to Firestone) San Gabriel River Estuary

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled For Completion (FY)
nitrogen and its effects	San Gabriel River Reaches 1, 2, 3 San Jose Creek Reaches 1 and 2 Coyote Creek Walnut Creek	02/03
Nitrogen and its effects	El Dorado Lakes Puddingstone Reservoir Legg Lake Santa Fe Dam Lake Crystal Lake	03/04
coliform	San Gabriel River Reaches 1 and 2 San Jose Creek Reaches 1 and 2 Coyote Creek	02/03
metals	San Gabriel River Reach 2 San Gabriel River Estuary Coyote Creek	04/05

We see a need for an additional 1.4 PYs as well as $200,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Stakeholder Groups

Los Angeles/San Gabriel Rivers Watershed Council: This group was formed in 1995 following a large watershed conference held in the area which served as a springboard for other efforts. The Council has a board of directors and became incorporated as a nonprofit organization in 1996. The group is tracking watershed activities, but has primarily focused on flood control issues in the Los Angeles River as well as opportunities to create greenbelts and restore habitat. The Council's goal is to help facilitate a process to preserve, restore, and enhance all aspects of the two watersheds. There has been interest recently to convene a subcommittee to address water quality issues in more detail. More information on this group may be found on their website http://www.lasgriverswatershed.org.

Friends of the San Gabriel River

The Friends of the San Gabriel River is a non-profit organization founded in 1999 that advocates water quality improvements, restoration of habitat, and increased access to the river for the public. More information on this group may be found on their website at http://www.sangabrielriver.org/.

Past Significant Activities

CORE REGULATORY

The Los Angeles County Storm Water Permit (which the San Gabriel River Watershed falls within) permit was renewed in July 1996. Individual NPDES permits in this watershed were renewed in FY99/00.

WATERSHED MANAGEMENT

An in-house team of staff completed a "State of the Watershed Report" for the San Gabriel River. This report is available by request as hardcopy or electronic files.

MONITORING AND ASSESSMENT

As part of a larger-scale investigation which concluded in 1996, ambient toxicity (as well as fish histopathology) was evaluated at a number of locations in the river which lead to additional 303(d) listings for impairments. The East Fork Trash TMDL (1999) documented the main sources of trash in the upper watershed.

Current Activities

The following is a summary of current regional board activities in the San Gabriel River Watershed which are expected to continue as part of the Watershed Management Initiative on a watershed basis.

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits. There are nine major dischargers, 25 significant or minor dischargers under individual permits, as well as 39 dischargers currently covered under general permits. Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue. All of the County Sanitation Districts' permits for their inland POTWs (which comprise most of the flow in the middle to lower river) are being renewed this year.

The San Gabriel River Watershed falls within Los Angeles County which was issued a renewed municipal storm water permit in 1996. There are 87 co-permittees covered under this permit including 85 cities, the County of Los Angeles, and the California Department of Transportation (Caltrans). Work on the permit will involve review of monitoring reports, evaluation of the storm water program's effectiveness, coordination with other watershed efforts, and modification of the permit as necessary. During 1997/98, discharger responsibilities under the permit concentrated on the evaluation of the five BMP model programs required in the 1996 permit: Illicit Connection/Illicit Discharges, Development Construction, Development Planning, Public Agency Activities, and Five-Year Public Education Strategy (including industrial/commercial site

visits). The watershed also falls partly within the City of Long Beach which was issued a municipal storm water permit in 1999.
An important requirement of both storm water municipal permits is implementation of the Standard Urban Storm Water Mitigation Plans (SUSMPs) and Numerical Design Standards for Best Management Practices (BMPs) which were adopted in 2000. The SUSMP is designed to ensure that storm water pollution is addressed in one of the most effective ways possible, i.e., by incorporating BMPs in the design phase of new development and redevelopment. It provides for numerical design standards to ensure that storm water runoff is managed for water quality concerns in addition to flood protection and that pollutants carried by storm water are retained and not delivered to waterways.

The numerical design standard is that post-construction treatment BMPs be designed to mitigate (infiltrate or treat) storm water runoff from the first ¾ inch of rainfall, prior to its discharge to a storm water conveyance system. Other standards also apply; additional information on the SUSMP may be found on the Regional Board website http://www.swrcb.ca.gov/~rwqcb4.

Due to limited resources, only the basic regulatory activities are performed: review of dischargers' monitoring reports, minimum necessary inspections and sampling, issuance/ renewal of permits, levels 1 and 2 enforcement actions (noncompliance and violation notification), case handling, and answering inquiries from the public.

NONPOINT SOURCE PROGRAM

The Regional Board encourages pollution prevention and source control; the 205(j), Prop 13, SRF, and 319(h) grants are tools to provide funds for these types of projects. For FY00/01, we have listed as a priority for 319(h) grant funding activities (see Table 3) which demonstrate effective ways to reduce loadings of trash, nutrients, and coliform through pilot projects which implement trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, or implementation of septic correction measures. High priority projects also include those involving restoration of aquatic and riparian habitats, as well as, enhancement of recreational uses.

MONITORING AND ASSESSMENT

In support of TMDL work, as well to obtain other needed information, we are requesting funding in order to start nitrogen, coliform, and metals TMDLs which are currently scheduled. We also plan on conducting ambient toxicity monitoring work and noted the need for a tidal prism mixing study to resolve issues concerning the fate of freshwater effluent in the estuary.

BASIN PLANNING

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

WETLANDS PROTECTION AND MANAGEMENT

The Southern California Wetlands Recovery Project considers the El Dorado Wetlands Restoration Plan a high priority for FY00/01 or future funding.

The San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy is an independent State agency within the Resources Agency. State law established the Conservancy in 1999. Its jurisdiction includes the San Gabriel River and its tributaries, the Lower Los Angeles River and its tributaries, and the San Gabriel Mountains. Puente Hills, and San Jose Hills. It was established to preserve open space and habitats in order to provide for low-impact recreation and educational uses, wildlife and habitat restoration and protection, and watershed improvements within its jurisdiction. It is currently involved with beginning work on an open space plan for the area. Propositions 12 and 13 have directed funds to the Conservancy.

The Santa Monica Mountains Conservancy is a state agency created by the Legislature in 1979 charged with primary responsibility for acquiring property with statewide and regional significance, and making those properties accessible to the general public. The Conservancy manages parkland in the Santa Monica Mountains, Santa Susana Mountains, the Simi Hills, the Santa Clarita Woodlands, the Whittier-Puente Hills, the Sierra Pelona, the Los Angeles River Greenway, the Rio Hondo, the Verdugo Mountains, the San Gabriel Mountains, and the San Rafael Hills. The agency's goals are to: 1) implement the Santa Monica Mountains Comprehensive Plan, 2) implement the Rim of the Valley Trails Corridor Master Plan, 3) implement the Los Angeles County River Master Plan, 4) further cooperation with local governments in the region to secure open space and parkland, and 5) expand education, public access, and resource stewardship components in a manner that best serves the public, protects habitat, and provides recreational opportunities.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j), Prop. 13, SRF, and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

Potential Long-term Activities

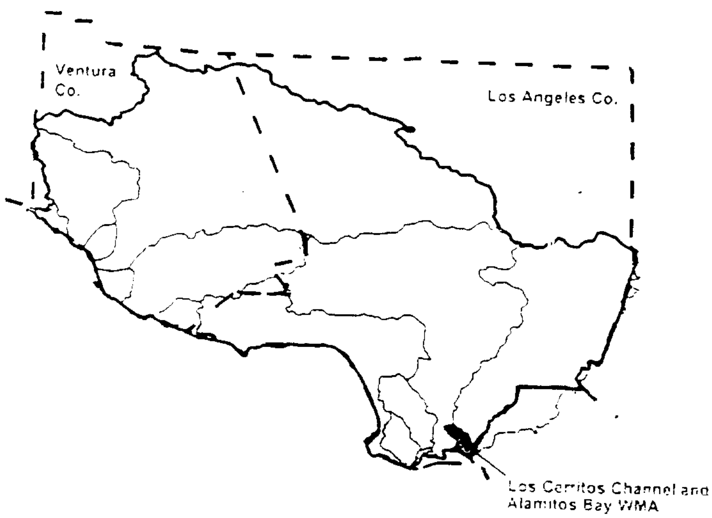
- Development of coordinated watershed monitoring program
- Hydrologic study of the estuary to evaluate mixing dynamics and effects on water quality and beneficial uses
- Evaluation of fish tissue from fish in the lower river and estuary
- Evaluation of toxicity impacts in the estuary
- Evaluation of habitats in the middle/lower river
- Evaluation of impacts from reservoir cleaning on water quality, particularly fisheries-related

- Evaluation of mining on instream beneficial uses
- Evaluation of impacts of reclaimed water on river/groundwater
- Evaluation of success of trash TMDL efforts in upper river
- Evaluation of impacts from industrial stormwater in the watershed
- Consideration of TMDL-related issues
- Implementation of biological monitoring

2.7 LOS CERRITOS CHANNEL AND ALAMITOS BAY WMA

This watershed will be targeted for permit renewal purposes in FY05/06.

Overview of WMA



Los Cerritos Channel, Tidal Prism, and Wetlands: The Los Cerritos Channel is concrete-lined above the tidal prism and drains a relatively small area of east Long Beach, albeit a densely urbanized one. The channel's tidal prism starts at Anaheim Road and connects with Alamitos Bay through the Marine Stadium; the wetlands connects to the Channel a short distance from the lower end of the Channel. The wetlands, and portion of the channel near the wetlands, is an overwintering site for a great diversity of birds (up to 50 species) despite its small size. An endangered bird species, the Belding's Savannah Sparrow, may nest there and an area adjacent to the wetlands is a historic least tern colony site. One small marina is located in the channel which is also used by rowing teams and is a popular fishing area.

Alamitos Bay: Alamitos Bay is composed of the Marine Stadium, a recreation facility built in 1932 and used for boating, water skiing, and jet skiing; Long Beach Marina, which contains five smaller basins for recreational craft and a boatyard; a variety of public and private berths; and the Bay proper which includes several small canals, a bathing beach, and several popular clamming areas. A small bathing lagoon, Colorado Lagoon in Long Beach, has a tidal connection with the Bay and a small wildlife pond, Sims Pond, also has a tidal connection. The latter is heavily used by overwintering migratory birds.

Beneficial uses designated in the watershed:

Estuary (marina, wetlands, bay)	*Above Estuary*
Contact & noncontact water recreation	Wildlife habitat
Industrial service supply	
Navigation	*Intermittent uses:*
Commercial & sportfishing	Noncontact water recreation
Estuarine habitat	Warmwater habitat
Marine habitat	
Wildlife habitat	
Preservation of rare & endangered species	
Migration of aquatic organisms	
Spawning habitat	
Shellfish harvesting	
Wetlands habitat	

Significant Issues:

- Loss of wetlands habitat in Los Cerritos area
- Impacts from antifouling paint in marinas
- Urban and storm water runoff

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Water Quality Problems and Issues

A considerable amount of leaching of boat paint likely occurs in the Bay, particularly in the marina. Nonpoint source runoff from storm drains are is also a likely source of problems.

Types of permitted wastes discharged into the Los Cerritos Channel WMA:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) filter backwash brine waters	1	Minor
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	2	General
Nonhazardous (designated) stormwater runoff	2 1	Minor General
Hazardous contaminated groundwater	1 1	Minor General
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	3	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

IMPAIRMENTS: Beneficial uses in the wetlands area are considered fully supported while those in the channel are not. Beneficial uses in the Bay are, for the most part, considered fully supported although Long Beach Marina is considered a site of concern due to elevated sediment concentrations of metals. The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Ammonia	Basin Plan narrative objective Basin Plan numeric objective: varies depending on pH and temperature but the general range is 0.53 - 2.7 mg/l of total ammonia (at average pH and temp.) in waters designated as WARM to protect against chronic toxicity and 2.3-28.0 mg/l to protect against acute toxicity	ND - 2.19 mg/l (mean of 0.34 ± 0.41)	Los Cerritos Channel
Copper (in tissue)	Basin Plan narrative objective		Los Cerritos Channel
Lead (in sediment)	Basin Plan narrative objective	510 ug/g (sediment)	Colorado Lagoon Los Cerritos Channel

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Zinc (in sediment)	Basin Plan narrative objective	690 ug/g (sediment)	Colorado Lagoon Los Cerritos Channel
chlordane (in tissue)	State Board numeric objective (tissue): Max. Tissue Residue Level 1.1 ng/g	64.9 ng/g (tissue)	Colorado Lagoon
DDT	State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	59.9 ng/g (tissue)	Colorado Lagoon
PCBs	State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	42.0 ng/g (tissue)	Colorado Lagoon
dieldrin	State Board numeric objective (tissue): Max. Tissue Residue Level 0.65 ng/g	18.2 ng/g (tissue)	Colorado Lagoon
sediment toxicity	Basin Plan narrative objective		Colorado Lagoon
coliform	Basin Plan numeric objective Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	2 - 170000 MPN/100ml	Los Cerritos Channel
PAHs	Basin Plan narrative objective	10,000 ng/g (sediment)	Colorado Lagoon

CURRENTLY SCHEDULED TMDLS:

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled For Completion (FY)
coliform	Los Cerritos Channel	04/05
ammonia	Los Cerritos Channel	04/05
metals	Los Cerritos Channel Colorado Lagoon	04/05
PAHs	Colorado Lagoon	04/05
Historic pesticides	Colorado Lagoon	04/05

Stakeholder Group

It is anticipated the Los Angeles/San Gabriel Watershed Council and the Friends of the San Gabriel River will function, at least initially, as this WMA's stakeholder groups. The Los Cerritos WMA is located between the Los Angeles and San Gabriel Rivers and drains to the same general area as the San Gabriel River. There is also a minor hydraulic connection between the lower San Gabriel River and Los Cerritos Channel due to the location of a power plant intake with the Long Beach Marina; the discharge from this facility is into the San Gabriel River estuary. Another potential stakeholder group is the Los Cerritos Wetlands Task Force http://www.loscerritos.org/.

Current Activities

The following is a summary of current regional board activities in the Los Cerritos Channel and Alamitos Bay Watershed which are expected to continue as part of the Watershed Management Initiative on a watershed basis. Please see the San Gabriel River Watershed Section for combined information on existing and needed resources for these two watersheds.

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits. There eight significant or minor dischargers under individual permits as well as seven dischargers currently covered under general permits. Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue.

The Los Cerritos Channel and Alamitos Bay WMA falls partly within Los Angeles County which was issued a renewed municipal storm water permit in 1996. There are 87 co-permittees covered under this permit including 85 cities, the County of Los Angeles, and the California Department of Transportation (Caltrans). Work on the permit will involve review of monitoring reports, evaluation of the storm water program's effectiveness, coordination with other watershed efforts, and modification of the permit as necessary. During 1997/98, discharger responsibilities under the permit concentrated on the evaluation of the five BMP model programs required in the 1996 permit: Illicit Connection/Illicit Discharges, Development Construction, Development Planning, Public Agency Activities, and Five-Year Public Education Strategy (including industrial/commercial site visits). The watershed falls mostly within the City of Long Beach which was issued a municipal storm water permit in 1999.

An important requirement of both storm water municipal permits is implementation of the Standard Urban Storm Water Mitigation Plans (SUSMPs) and Numerical Design Standards for Best Management Practices (BMPs) which were adopted in 2000. The SUSMP is designed to ensure that storm water pollution is addressed in one of the most effective ways possible, i.e., by incorporating BMPs in the design phase of new development and redevelopment. It provides for numerical design standards to ensure that storm water runoff is managed for water quality concerns in addition to flood protection and that pollutants carried by storm water are retained and not delivered to waterways.

The numerical design standard is that post-construction treatment BMPs be designed to mitigate (infiltrates or treat) storm water runoff from the first ¾ inch of rainfall, prior to its discharge to a storm water conveyance system. Other standards also apply; additional information on the SUSMP may be found on the Regional Board website http://www.swrcb.ca.gov/~rwqcb4.

NONPOINT SOURCE PROGRAM

The Regional Board encourages pollution prevention and source control; the 205(j) and 319(h) grants are tools to provide funds for these types of projects. For FY00/01, we have listed as a priority for 319(h) grant funding activities (see Table 3) which restore aquatic and riparian habitats and those that enhance recreational uses.

BASIN PLANNING

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

WETLANDS PROTECTION AND MANAGEMENT

The Southern California Wetlands Recovery Project has identified acquisition of an option on the 185-acre Bixby and100-acre Hellman Ranch parcels (which are in the area of the wetlands) priority projects for FY00/01 or future funding.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities and TMDLs in this area.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

Potential Long-term Activities

- Evaluation of existing conditions/beneficial uses
- Consideration of TMDL-related issues
- Implementation of biological monitoring

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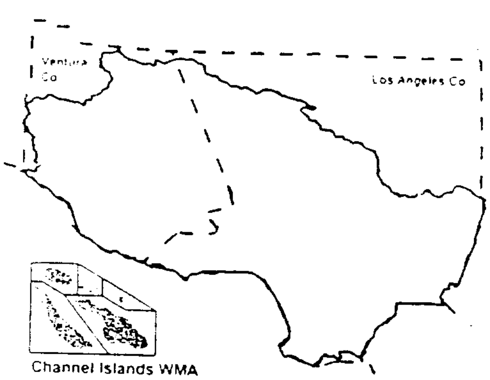
2.8 *THE CHANNEL ISLANDS WMA*

This watershed will be targeted for permit renewal purposes in FY05/06.

Overview of WMA



Channel Islands WMA

The Channel Islands within the Region's boundaries are: Anacapa, San Nicolas, Santa Barbara, Santa Catalina, and San Clemente Islands. Anacapa and Santa Barbara Islands are part of the Channel Islands National Park. The waters within six nautical miles of Anacapa and Santa Barbara Islands are designated a national marine sanctuary. The ocean waters adjacent to the islands (not the entire circumference of Santa Catalina however) were designated Areas of Special Biological Significance by the state of California. The west side of San Nicolas supports a large gull rookery and elephant seal breeding area. The U.S. Navy has facilities on San Nicolas (and a desalination plant) and San Clemente Islands with a small package treatment plant on the latter. The city of Avalon is located on Santa Catalina Island and also has a small treatment plant.

Beneficial Uses of Island Watercourses

Municipal supply
Groundwater recharge
Contact & noncontact water recreation
Warmwater habitat
Wildlife habitat
Preservation of rare & endangered species

Water Quality Problems and Issues

Water quality in the vicinity of the islands is uniformly good. There are some potential threats from naval facilities and small treatment plants; however, no part of this watershed management area is on the 303(d) list.

Types of permitted wastes discharged into the Channel Islands WMA:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) filter backwash brine waters	2	Minor
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	1	Minor
Nonhazardous (designated) domestic sewage	1 1	Major Minor

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain non**hazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Nonhazardous wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Inert wastes are those influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

Stakeholder Group

There is currently no stakeholder group organized for the islands.

Current Activities

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits. There is one major discharger (sewage treatment plant on Santa Catalina Island) and four significant or minor dischargers under individual permits. Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue.

The Channel Islands WMA

- Five islands
- One major discharger, four minor dischargers
- Areas offshore of islands designated as Areas of Special Biological Significance
- High quality marine and rocky intertidal habitat
- Heavy use by marine mammals and endangered species

Due to limited resources, only the basic regulatory activities are performed: review of dischargers' monitoring reports, minimum necessary inspections and sampling, issuance/renewal of permits, levels 1 and 2 enforcement actions (noncompliance and violation notification), case handling, and answering inquiries from the public.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

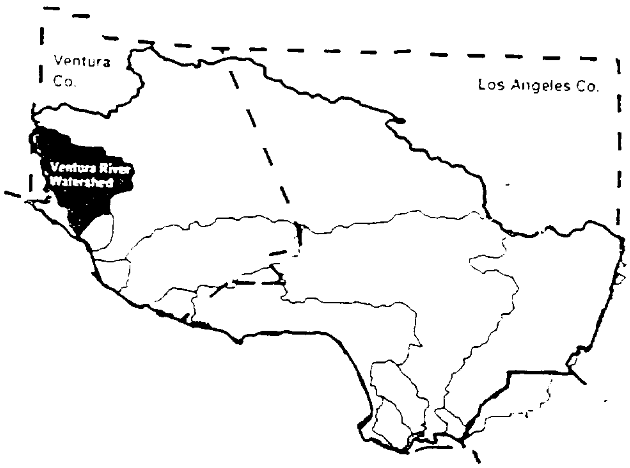
The Channel Islands WMA is being proposed for inclusion in a partial update of the Water Quality Assessment report due in 2002. Some staff resources will be needed in 2001/02 to gather and analyze existing data.

We will maintain involvement with island activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. As resources permit, we will also work with stakeholders to implement provisions of the Coastal Zone Act Reauthorization Amendments.

2.9 *VENTURA RIVER WATERSHED*

This was a targeted watershed for permitting purposes in FY95/96 and FY00/01.

Overview of Watershed



The Ventura River and its tributaries drain a coastal watershed in western Ventura County. The watershed covers a fan-shaped area of 235 square miles, which is situated within the western Transverse Ranges (the only major east-west mountain ranges in the continental U.S.). From the upper slopes of the Transverse Ranges, the surface water system in the Ventura River watershed generally flows in a southerly direction to an estuary, located at the mouth of the Ventura River. Groundwater basins composed of alluvial aquifers deposited along the surface water system, are highly interconnected with the surface water system and are quickly recharged or depleted, according to surface flow conditions. Topography in the watershed is rugged and as a result, the surface waters that drain the watershed have very steep gradients, ranging from 40 feet per mile at the mouth to 150 feet per mile at the headwaters.

Beneficial Uses in Watershed:

Estuary	*Above Estuary*
Navigation	Municipal supply
Commercial & sportfishing	Industrial service supply
Estuarine habitat	Industrial process supply
Marine habitat	Agricultural supply
Contact & noncontact water recreation	Contact & noncontact water recreation
Warmwater habitat	Warmwater habitat
Wildlife habitat	Wildlife habitat
Preservation of rare & endangered species	Preservation of rare & endangered species
Migratory & spawning habitat	Migratory & spawning habitat
Wetlands habitat	Wetlands habitat
Shellfish harvesting	Coldwater habitat
	Groundwater recharge
	Freshwater replenishment

Precipitation varies widely in the watershed. Most occurs as rainfall during just a few storms, between November and March. Summer and fall months are typically dry. Although snow occurs at higher elevations, melting snowpack does not sustain significant runoff in warmer months. The erratic weather pattern, coupled with the steep gradients throughout most of the watershed, result in high flow velocities with most runoff reaching the ocean.

Water Quality Problems and Issues

The majority of water quality problems involve eutrophication (excessive nutrients and effects), especially in the estuary/lagoon although some DDT and metals have been found in mussel and fish tissue (on the 303(d) list for these). A large storm drain enters the river near the estuary and homeless persons live in and frequent the river bed. Sediment in the estuary, however, appears relatively uncontaminated and in laboratory tests conducted through the Bay Protection and Toxic Cleanup Program, little sediment toxicity was found. In some sub- watersheds, high TDS concentrations impair the use of water for agriculture. The watershed's water quality problems are, for the most part, nonpoint source-related. There have also been incidents of releases of toxic materials into storm drains entering the lower river.

The Ventura River Watershed

- One major discharger (POTW)
- 27 dischargers covered under industrial stormwater permit
- Eutrophication concerns, especially in lagoon
- Some bioaccumulation of DDT and metals
- TDS concerns in some subwatersheds
- Impediments to steelhead trout migration (but much high quality habitat)

There is only one major discharger, a small POTW (3.0 MGD) in the middle reach of the Ventura River which has recently upgraded (end of 1997) to tertiary treatment The treatment plant effluent had been implicated in nuisance growth of aquatic plants and low dissolved oxygen found at times downstream of the discharge. For much of the year, the facility's effluent can make up two-thirds of the total river flow. The major concern was the facility's inability to meet the nutrients and suspended solids discharge limitations in its NPDES permit. Additionally, high biochemical oxygen demand (BOD) in the effluent resulted in dissolved oxygen concentrations in the river that could not support cold water aquatic habitat. The facility was required to upgrade under a Regional Board Cease and Desist Order. The most recent monitoring has shown the quality of the effluent has significantly improved including a reduction of nitrate-nitrogen from 20 mg/l to 4 mg/l, a reduction of suspended solids from 12 mg/l to 2 mg/l, and a reduction of BOD from 10 mg/l to 2 mg/l. DO levels in the river have improved dramatically to about 11 mg/l and algal growth is greatly reduced below the plant; however, nonpoint sources (agriculture and horse stables) still appear to be contributing to algal growth above the plant.

Types of permitted wastes discharged into the Ventura River Watershed:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) domestic sewage & industrial waste	1	Major
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	4	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
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Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

Of the 27 dischargers enrolled under the general industrial storm water permit in the watershed, the largest numbers fall in the *Motor Freight Transportation and Warehousing*; *Food and Kindred Products*; and *Oil and Gas Extraction* categories.

Water diversions, dams, and groundwater pumping also are thought to limit surface water resources needed to support a high quality fishery. Reduced water supplies affect water quality and thus beneficial uses, particularly with regards to the endangered steelhead trout (steelhead trout are known to utilize the River and some of its tributaries historically supported annual steelhead runs of 5000 – 6000 adults). Removal of the Matilija Dam (upper river) has recently been identified as a high priority.

The table below gives examples of typical data ranges which led to the 1998 303(d) listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

IMPAIRMENTS:

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
DDT	Basin Plan narrative objective	23.0 ng/g (tissue)	Ventura River Estuary
Algae	Basin Plan narrative objective		Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.) Ventura River Estuary
Pumping, Water diversions	Basin Plan narrative objective		Ventura River Reach 4 (Coyote Creek to Camino Cielo Rd.) Ventura River Reach 3 (Weldon Canyon to confl. w/ Coyote Cr.)
Copper	Basin Plan narrative objective	4.1 ug/g (tissue)	Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.)
Silver	Basin Plan narrative objective	0.03 ug/g (tissue)	Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.)
Zinc	Basin Plan narrative objective	40.0 ug/g (tissue)	Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.)
Trash	Basin Plan narrative objective		Ventura River Estuary
Se	Basin Plan narrative objective	2.2 ug/g (tissue)	Ventura River Reach 2 (Main St. to Weldon Canyon)

CURRENTLY SCHEDULED TMDLS

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
eutrophication	Ventura River Reaches 1 and 2 Ventura River Estuary	04/05

We see a need for an additional 1.3 PYs as well as $50,000 in contract dollars for FY00/01 TMDL work conducted in this watershed.

Stakeholder Group

Ventura River Steelhead Restoration and Recovery Plan Group A Plan was developed in response to the listing of steelhead trout as an endangered species by the National Marine

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Fisheries Service (NMFS) in August 1997. The plan was developed 1) to identify measures to mitigate impacts of ongoing operations and maintenance activities, 2) to identify future projects and, 3) identify and evaluate opportunities to promote recovery and restoration of the steelhead trout in the watershed. One staff person will continue to remain involved with the group, as needed.

Preliminary State of the Watershed Report Staff completed a Preliminary State of the Watershed Report for the Ventura River in 1995.

Significant Past Activities

In August 1997, the National Marine Fisheries Service (NMFS) listed the steelhead trout in Southern California as endangered under the Federal Endangered Species Act (ESA). The listing means that any project or action that may affect steelhead trout or their habitats will require consultation with NMFS to obtain an incidental take permit. In order to prepare for the listing and deal with possible regulatory requirements as a result of the listing, the Casitas Municipal Water District, City of Ventura, Ventura County Flood Control District, and seven other local public and private agencies collaborated and developed the **Ventura River Steelhead Restoration and Recovery Plan** in December 1997 (see above). The plan also contains large amount of background information on the watershed such as hydrology, biology, steelhead habitat conditions, and the operations and maintenance of water wastewater, solid waste, transportation and flood control facilities of the sponsoring agencies. The regulatory activities by the Regional Water Quality Control Board in the watershed were briefly reviewed in the plan.

Current Activities

The following is a summary of current regional board activities in the Ventura River Watershed which are expected to continue as part of the Watershed Management Initiative on a watershed basis.

CORE REGULATORY

Permits in this watershed were renewed together in June 1996; this watershed will be targeted again in FY2000-01. The Ventura County Municipal Stormwater Permit is scheduled for reissuance in spring 2000. Continuing core regulatory activities include compliance inspections, reviewing of monitoring reports, response to complaints, and enforcement actions as needed. Key regulatory staff will continue to remain involved in the Ventura River Watershed Team for purposes of coordinating watershed activities in-house and working on any needed State of the Watershed Report updates.

Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Municipal Storm Water Permit (adopted in 2000). Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Ventura County Municipal Storm Water Program. The "Discharger" consists of the co-permittees Ventura County Flood Control District, the County of Ventura, and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks. The Discharger is required to implement the approved Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) by January 27, 2001. The SQUIMP shall address conditions and requirements for new development and significant redevelopment.

The Ventura River receives municipal storm drain discharges from the City of Ojai, City of San Buenaventura (part), and unincorporated Ventura County (part).

To date, the storm water monitoring program has consisted of land-use based monitoring combined with receiving water monitoring and modeling. The Discharger intends to sign an agreement to participate in the Regional Monitoring Program established for Southern California municipal programs under the guidance of the Southern California Coastal Water Research Project.

Currently under consideration are agreements with sister agencies in regulatory-based encouragement of Best Management Practices. Most notably is the use of a GIS layer for pesticides application available from the Department of Pesticide Regulation (DPR). Reduction of pesticides identified as contaminants of concern for a watershed might be addressed through a Management Agency Agreement (MAA) with the DPR, or through waiving adoption of waste discharge requirements on an individual basis using information gathered in databases provided by the Ventura County Agricultural Commission office.

MONITORING AND ASSESSMENT

A receiving water monitoring program is implemented by the Ojai Valley Sanitary District, supplemented by ambient or special monitoring conducted by Regional Board staff. The monitoring supports compliance evaluation, nonpoint source identification, and potential TMDL development. Ventura River Watershed TMDL-type activities investigated sources of low dissolved oxygen in the river in the area of the treatment plant. In conjunction with the receiving water monitoring, land-use based monitoring is done as part of the Ventura County Municipal Storm Water Program. We would also like to begin early monitoring for 303(d) parameters in 2001, with a potential de-listing of some of the current 303(d) parameters.

WETLANDS PROTECTION AND MANAGEMENT

The Southern California Wetlands Recovery Project considers the removal of Matilija Dam on Matilija Creek, a tributary to the Ventura River northwest of Ojai a strong contender for funding in FY00/01 and future years. According to the US Fish & Wildlife Service, the removal would accomplish 1) restoration of the Ventura River ecosystem and contribute to recovery of endangered steelhead trout, 2) provide needed sediment for beach nourishment and coastal erosion control, and 3) facilitate recreational access to Matilija Wilderness Area in the Los Padres National Forest. Other projects under discussion involve land acquisitions at the mouth of the river. This habitat is primarily riparian.

NONPOINT SOURCE PROGRAM

A priority issue is continued work to determine the scope of water quality impacts from agricultural runoff in the Region. Some agricultural activities occur in the Ventura River Watershed. Development of solutions to any impacts is also a high priority and will be a major concern of the nonpoint source program and, by extension, watershed groups which will be addressing this as well as other problems.

Staff will pursue re-initiating stakeholder meetings in the watershed and assist in development of a watershed management plan which will be expected to address strategies to reduce point and nonpoint source pollutants as well as issues other than strictly water quality concerns. In the meantime, staff will remain involved with the agencies that collaborated to develop a plan for restoration and recovery of anadramous steelhead trout in the watershed. An example of regulatory-based encouragement can be found in this plan development. Equestrian stables in the San Antonio Creek tributary of the river were identified by Regional Board and U.S. Army Corps of Engineers staff as existing and potential sources of problems in the watershed. Facility owners are working to improve their operations from a water quality standpoint in an effort to avoid implementation of management practices under Waste Discharge Requirements.

BASIN PLANNING

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

Review of and comment for the highest priority EIRs in the watershed will continue although this is currently an unfunded program.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

Near-term **Basin Planning** issues include addressing impacts from hydromodification and pumping, particularly in steelhead trout restoration and dam removal efforts, and developing nutrient standards for the lagoon.

Potential Long-term Activities

Baseline watershed-wide bioassessment monitoring in this largely natural watershed will be an important component of any long-term planning and assessment. There are currently no funds for this type of activity.

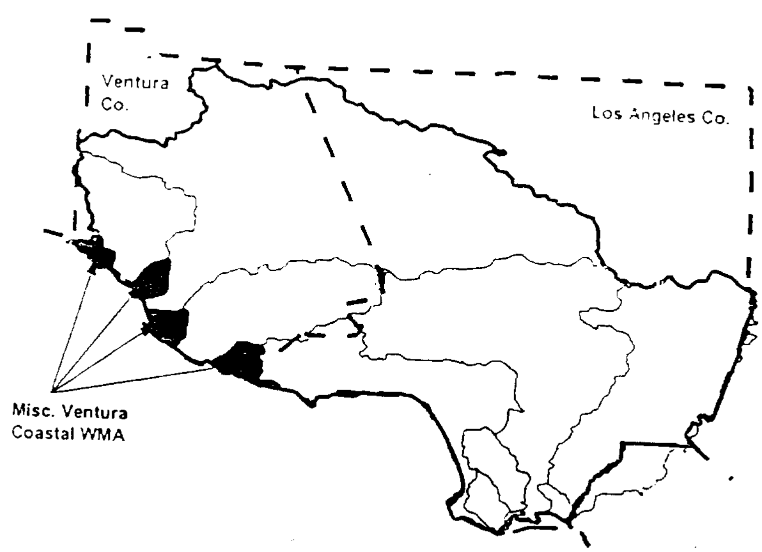
We will be involved to some extent with discussions concerning the proposal to decommission and remove the Matilija Dam. The Ventura County Board of Supervisors voted to request legislation be introduced to fund a Reconnaissance Study by the U.S. Army Corps of Engineers on that matter.

2.10 *MISCELLANEOUS VENTURA COASTAL WMA*

This Watershed Management Area was targeted for permitting purposes in FY00/01.

Overview of WMA

Channel Islands Harbor: Channels Islands Harbor is located south of the Santa Clara River and is in the immediate vicinity of considerable residential development and some agricultural land. The Southern California Edison inlet canal to the Ormond Beach Generating Station is located at the north end of the harbor. The harbor is home to many recreational boats and two boatyards.



Port Hueneme Harbor: Port Hueneme is a medium-sized deepwater harbor located in Ventura County, north of Mugu Lagoon. Part of it was operated by a U.S. Navy Construction Battalion until very recently while the rest of the harbor serves as a commercial port operated by the Oxnard Harbor District. The construction of a majority of the harbor was completed in 1975. The commercial side generally serves ocean-going cargo vessels and oil supply boats; the latter serve the oil platforms in the Santa Barbara Channel. Two endangered bird species may use the harbor, the California Brown Pelican and the California Least Tern.

Ventura Marina: Ventura Marina is a small craft harbor located between the mouths of the Ventura and Santa Clara Rivers. It is home to numerous small boats and two boatyards. The "Ventura Keys" area of the marina is a residential area situated along three canals. The marina is surrounded by agricultural land and a large unlined ditch drains into the Keys area. Since the marina is between the mouths of two rivers which discharge large sediment loads from their relatively undeveloped watersheds, the marina has a constant problem with keeping the entrance channel open.

McGrath Lake: McGrath Lake is a small brackish waterbody located just south of the Santa Clara River. The lake is located partially on State Parks land and partially on privately-owned oilfields in current production. A number of agricultural ditches drain into the lake. A state beach is located off the coastal side of the lake. The habitat around the lake is considered to be quite unique and it is utilized by a large number of overwintering migratory birds.

Beneficial Uses in WMA

Channel Islands Harbor
Industrial service supply
Contact & noncontact water recreation
Navigation
Commercial & sportfishing
Marine habitat
Wildlife habitat

Port Hueneme Harbor
Process water supply
Contact & noncontact water recreation
Navigation
Commercial & sportfishing
Marine Habitat
Wildlife habitat

Ventura Marina
Industrial service supply
Contact & noncontact water recreation
Navigation
Commercial & sportfishing
Marine habitat
Wildlife habitat
Shellfish harvesting

Ormond Beach
Industrial water supply
Contact & noncontact water recreation
Wildlife habitat
Wetlands habitat
Protection of rare & endangered species
Navigation
Power generation
Commercial & sportfishing
Marine habitat
Shellfish harvesting

Ormond Beach Wetlands and McGrath Lake
Estuarine habitat
Contact & noncontact water recreation
Wildlife habitat
Wetlands habitat
Protection of rare & endangered species

Open Coastline: A major feature of the coastline north of Mugu Lagoon is Ormond Beach and Ormond Beach Wetlands. There are a number of scenarios under consideration for restoration of this degraded yet valuable wetlands.

Water Quality Problems and Issues

Channel Islands Harbor: The harbor is on the 1998 303(d) list for lead and zinc. During the early to mid-1980s, the SMWP found low to intermediate levels of metals and organics except for one especially high accumulation of DDT. Sediment sampling for metals conducted by Regional Board staff in 1988 revealed slightly to moderately elevated levels. Copper at one site was nearly 50 ppm and zinc was as high as 76 ppm. Arsenic was slightly elevated (4 ppm) at a sampling site located next to a drain possibly connected to a nearby agricultural field. Under the BPTCP, the harbor is listed as site of concern due to DDT and silver sediment concentrations and sediment toxicity (but not recurrent toxicity); further monitoring is needed here.

The harbors
- One deepwater harbor and two small-craft marinas
- Accumulation of metals, PCBs, and historic pesticides in sediment and tissue
- Support considerable marine life

The wetlands and coast
- Historic pesticide contamination
- Loss of quality habitat
- Impacts from oil spills
- Use by endangered species

Port Hueneme Harbor: The harbor is on the 1998 303(d) list for PAHs, DDT, PCBs, TBT, and zinc. The SMWP has found elevated levels of Cu, Zn, PAHs, and PCBs. Zinc was at elevated levels on the commercial side while PCBs were very high on the Navy side. The Navy side is suspected of using large amounts of pentachlorophenol (PCP) for treatment of wood pilings. An Army Corps DEIR released in 1985 covering extension of one channel stated that water quality was good. The document also briefly discussed the port's biota which CDFG found to be "fairly healthy" and typical of southern California harbors. Sediment core samples were collected in 1985 as part of a proposed dredge project. Relatively low levels of metals were found and no pesticides were detected. It may well be that flushing is good in the harbor and only locating a station directly next to a source will result in bioaccumulation. The BPTCP found fairly minimal levels of sediment toxicity in recent testing but the harbor is considered a site of concern under the program due to accumulation of DDT, PCBs, TBT, PAHs, and zinc in mussel tissue. Further monitoring is needed here.

Ventura Marina: The marina (the Keys area) is on the 1998 303(d) list for coliform problems. The City of Ventura monitors six stations within the Keys and the nearby Arundell Barranca (open drain carrying mostly agricultural runoff) for coliform on a regular basis. There are currently ongoing discussions concerning the possibility of re-rerouting the barranca away from the marina. The SMWP has found moderately elevated levels of metals, DDT, and chlordane in the marina from sampling conducted in the late 1980s; however, it is not listed as a site of concern under the BPTCP.

McGrath Lake: The lake is on the 1998 303(d) list for pesticides. The BPTCP found varying amounts of sediment toxicity and sediment levels of many pesticides were very high; the lake is listed as a toxic hot spot due to sediment concentrations of DDT, chlordane, dieldrin, toxaphene and endosulfan above sediment quality guidelines. A characterization study is ongoing and restoration work is being planned. A major crude oil spill into the lake occurred in late 1993 and runoff from nearby agricultural fields is ongoing.

Open Coastline: Little is known of water quality in the Ormond Beach area. The Oxnard Treatment Plant discharges secondary effluent to the ocean off of Oxnard. The facility is currently investigating approaches to remove upstream brine dischargers in order to move toward water reclamation. Part of the reclaimed water is proposed for use in a seawater intrusion barrier project to protect the Oxnard Plain ground water basin. The ocean immediately off of the coast was part of Bight'98 and the 1994 Southern California Bight Pilot Project.

Types of permitted wastes discharged into the Misc. Ventura Coastal WMA:

Nature of Waste *Prior* to Treatment or Disposal	# of Permits	Types of Permits
Nonhazardous (designated) contaminated groundwater	1	Minor
Nonhazardous (designated) domestic sewage & industrial waste	1	Major
Nonhazardous (designated) wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage	5 4	Minor General
Nonhazardous (designated) noncontact cooling water	1	Major
Nonhazardous (designated) process waste (produced as part of industrial/manufacturing process)	1 1	Major Minor
Nonhazardous (designated) stormwater runoff	1	Minor
Nonhazardous (designated) filter backwash brine waters	1	Minor
Nonhazardous (designated) washwater waste (photo reuse washwater, vegetable washwater)	1	Minor
Inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage)	2	General

Hazardous wastes are those influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated wastes are those influent or solid wastes that contain **nonhazardous** wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
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Major discharges are POTWs with a yearly average flow of over 0.5 MGD or an industrial source with a yearly average flow of over 0.1 MGD and those with lesser flows but with acute or potential adverse environmental impacts.

Minor discharges are all other discharges that are not categorized as a Major. Minor discharges may be covered by a general permit, which are issued administratively, for those that meet the conditions specified by the particular general permit.

The table below gives examples of typical data ranges which led to the listings. See Table 7 in the Appendix for additional details on currently scheduled TMDLs as well as specific pollutants included in the TMDLs.

IMPAIRMENTS:

Impairments	Applicable Objective/Criteria	Typical Data Ranges Resulting in Impairment	303(d) Listed Waters/Reaches
Beach closures	Basin Plan narrative objective	10 - 37 days/year closed	McGrath Beach Mandalay Beach
Coliform	Basin Plan numeric objective. Inland: fecal coliform not to exceed log mean of 200 mpn/100ml in 30-day period and not more than 10% of samples exceed 400 MPN/100ml Beaches: total coliform not to exceed 1,000 MPN/100ml in more than 20% of samples in 30 days and not more than 10,000 MPN/100ml at any time	Objective was exceeded from 32 - 75% of time	Santa Clara River Estuary Beach/Surfers Knoll McGrath Beach Ventura Harbor: Ventura Keys
Sediment toxicity	Basin Plan narrative objective		
Chlordane (sediment)	Basin Plan narrative objective		McGrath Lake
DDT (sediment & Tissue)	Basin Plan narrative objective	160 ng/g	McGrath Lake
	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 32.0 ng/g	3,000 ng/g (sediment) 700 ng/g (tissue)	McGrath Lake Port Hueneme Harbor
PCBs (tissue)	Basin Plan narrative objective State Board numeric objective (tissue): Max. Tissue Residue Level 2.2 ng/g	2,000 ng/g	Port Hueneme Harbor
PAHs (sediment)	Basin Plan narrative objective	10,000 ng/g	Port Hueneme Harbor
Zinc (sediment & tissue)	Basin Plan narrative objective	320 - 400 ng/g (tissue) 380 ng/g (sediment)	Port Hueneme Harbor
Lead (sediment)	Basin Plan narrative objective	180 ng/g	Channel Islands Harbor
Tributyl tin (tissue)	Basin Plan narrative objective	7,000 ng/g	Channel Islands Harbor Port Hueneme Harbor

CURRENTLY SCHEDULED TMDLS

Type of TMDL	Listed Waters/Reaches in TMDL	Year Scheduled for Completion (FY)
coliform	McGrath Beach Mandalay Beach	01/02
zinc	Port Hueneme Harbor	04/05

We see a need for an additional 0.7 PY for FY00/01 TMDL work conducted in this watershed.

Stakeholder Group

Ormond Beach Task Force Ormond Beach is part of the Miscellaneous Ventura Coastal WMA; the area includes a somewhat degraded wetlands which has considerable restoration potential. The Task Force was formed in 1993 and meets on an infrequent basis to address issues and projects which may affect the beach and wetlands.

Current Activities

Both existing and needed resources are presented in a table in the "Near-term Activities" subsection.

CORE REGULATORY

Continuing core regulatory activities that will be integrated into the watershed management approach include (but are not limited to) necessary renewal/revision of NPDES permits. This will be a targeted watershed for the bulk of permit renewal purposes in FY 2000-01. There are three major dischargers, 13 significant or minor dischargers under individual permits, as well as one discharger currently covered under a general permit (additional information on permits may be found in the Appendix). Compliance inspections, review of monitoring reports, response to complaints, and enforcement actions relative to the watershed's NPDES permits will continue.

Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Municipal Storm Water Permit (adopted in 2000). Additionally, most urban areas in Ventura County, including this watershed, are implementing Best Management Practices under the Ventura County Municipal Storm Water Program. The "Discharger" consists of the co-permittees Ventura County Flood Control District, the County of Ventura, and the Cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks. The Discharger is required to implement the approved Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) by January 27, 2001. The SQUIMP shall address conditions and requirements for new development and significant redevelopment.

The Miscellaneous Ventura Coastal WMA receives municipal storm drain discharges from the City of Oxnard (part), City of Port Hueneme, and City of San Buenaventura (part).

To date, the storm water monitoring program has consisted of land-use based monitoring combined with receiving water monitoring and modeling. The Discharger intends to sign an agreement to participate in the Regional Monitoring Program established for Southern California municipal programs under the guidance of the Southern California Coastal Water Research Project.

MONITORING AND ASSESSMENT

The Ventura Coastal drainages are being proposed for inclusion in a partial update of the Water Quality Assessment report due in 2002. Staff resources will be needed in 2000/01 to prepare the update. The monitoring needs in this WMA include staff to evaluate coastal receiving water data, sediment data analysis and interpretation, resources to integrate surface and ground water data, and resources to evaluate other information (e.g., pesticide and fertilizer use databases as well as those for grower/crop and crop timing).

McGrath Lake: A Consent Decree established a settlement with the responsible party in a 1993 crude oil spill. The settlement created a Trustee Council (California Department of Fish and Game, U.S. Fish and Wildlife Service, and California Department of Parks and Recreation) to determine how to spend $1.315 million targeted for natural resource restoration.

The Trustee Council formally requested assistance from the Regional Board to perform a study to characterize the water quality and sediments within the lake, as well as sources of contaminant inputs to the lake. The main objectives of the study were to determine whether it would be necessary or beneficial to dredge the lake to remove contaminated sediments, and whether it would be beneficial to spend funds on habitat improvement projects in and around the lake, given the ongoing potential contaminant inputs and uncontrolled water management activities. The Regional Board funded the characterization study (contributing $100,000) using some of the money the Board received from the oil spill settlement.

A preliminary study was conducted in August 1998 to aid in selection of sampling sites for the characterization study. The characterization study was conducted in October 1998 and included:

1) water quality measurements at several locations in the lake (temperature, dissolved oxygen, pH, and nutrient data)

2) surficial sediment samples at 10 stations in the lake will be analyzed for grain size, sediment chemistry (pesticides, petroleum hydrocarbons, metals) and sediment toxicity

3) deep sediment cores at 7 stations in the lake will be subsampled for sediment chemistry analyses

4) water column measurements at one station in an agricultural drain entering the lake (pesticides, metals, and nutrients)

5) sediment chemistry (pesticides and metals) at 2 stations in agricultural drains

The characterization study demonstrated widespread sediment contamination throughout most of the lake, including high concentrations of several trace metals and pesticides. Prior to undertaking a sediment cleanup and habitat restoration program, it would be useful to eliminate or reduce on-going sources of contamination, e.g., agricultural runoff. The Trustee Council plans to release a restoration plan in 2001 and work with local stakeholders to develop solutions to these problems.

Shoreline: Beginning in 1999, a new law requires public health officials in coastal counties to conduct weekly testing, between April 1 and October 31, at beaches visited annually by more than 50,000 people and at adjacent storm drains (including natural creeks, streams, and rivers, that flow during the summer. Due to the popularity of Ventura County beaches for year-round activities, the Ventura County Board of Supervisors authorized the implementation of a program that expanded the monitoring program to all 12 months of the year. Ventura County Environmental Health Department will conduct routine surf zone sampling at 52 beach locations. Data will be reviewed by the Regional Board and used to assess current conditions of Ventura County beaches for future 305(b) reports.

Open Coastline: Our source of data for the coastal areas comes chiefly from the one POTW and two generating stations which discharge offshore as well as regional data from Bight'98 and the 1994 SCBPP. These data support compliance evaluation.

WETLANDS PROTECTION AND MANAGEMENT

The Southern California Wetlands Recovery Project has listed Ormond Beach Wetlands acquisition and preparation of a restoration plan as a priority project for FY00/01 or future funding. The project involves acquisition of 600 acres of wetlands and dunes parcels privately-owned and implementation of an existing restoration plan for these parcels. Acquisition of land in the McGrath Lake area is also a high priority.

BASIN PLANNING

Basin Planning activities will include continued participation in both internal and external watershed planning efforts and further incorporation of watershed management and principles and watershed-specific priorities into future updates of the Basin Plan, where appropriate.

NONPOINT SOURCE PROGRAM

We are encouraging application for Proposition 13 funding for use in preparation of a watershed management plan for this watershed management area.

Groundwater

The Oxnard Forebay is a prime groundwater recharge area that is impacted by nitrogen discharges, mainly from densely populated communities using septic systems, and agricultural areas. The Regional Board undertook a study of septic systems in the area during FY98/99; in August 1999 the Board adopted a Basin Plan amendment to prohibit septic systems in the Oxnard Forebay. The amendment immediately prohibits the installation of new septic systems or the expansion of existing septic systems on lot sizes of less than five acres. Discharges from septic systems on lot sizes of less than five acres must cease by January 1, 2008. This prohibition will affect up to 3,000 septic systems and ten to fifteen thousand people. The County of Ventura has applied for Small Community Grant funding to provide adequate sewage treatment on behalf of the Saticoy and El Rio communities.

Another **319(h)** project is underway which also involves septic tanks. The Scope of Work for this project is still being developed but will involve the evaluation of several systems for nutrient removal.

A well head protection and demonstration project in the Fox Canyon Groundwater Management Area is being funded with **319(h)** monies. This project is destroying disused drinking water wells which may serve as a conduit for contamination to reach the deep water aquifer.

Currently under consideration are agreements with sister agencies in regulatory-based encouragement of Best Management Practices. Most notably is the use of a GIS layer for pesticides application available from the Department of Pesticide Regulation (DPR). Reduction of pesticides identified as contaminants of concern for a watershed might be addressed through a Management Agency Agreement (MAA) with the DPR, or through waiving adoption of waste discharge requirements on an individual basis using information gathered in databases provided by the Ventura County Agricultural Commission office.

Marinas

There are a number of marinas in this WMA, all with well-documented levels and types of pollution consistent with nonpoint sources. We have initiated enforcement actions on several commercial fishing operations to ensure compliance with state discharge requirements. We will be focusing our 319(h) priorities for the upcoming application period on a number of areas of concern in the Region including development of education and outreach programs and implementation of management measures which are intended to reduce pollution from these nonpoint sources in marinas. A particular area of concern in Port Hueneme has been management of squid wastes from fishing vessels.

Near-term Activities

Specific resource needs are described in the Region-wide Section of this document.

A preliminary review of resources for core regulatory activities against cost factors has determined that our region is seriously underfunded for our baseline program. We will be seeking more funding for our core program activities.

The Ventura Coastal drainages are being proposed for inclusion in a partial update of the Water Quality Assessment report due in 2002. Staff resources will be needed in 2000/01 to prepare the update. The monitoring needs in this WMA include staff to evaluate coastal receiving water data, sediment data analysis and interpretation, resources to integrate surface and ground water data, and resources to evaluate other information (e.g., pesticide and fertilizer use databases as well as those for grower/crop and crop timing).

Most watershed programs look to the Regional Board as the information management agency for the collected data. To meet that need, we require additional resources related to data management and interpretation. Some of the expenditures under NPDES support the monitoring that will ultimately be used to identify and quantify nonpoint source inputs.

We will maintain involvement with stakeholder activities and pursue funding options, especially those involving implementation of nonpoint source measures (coordinate 205(j) and 319(h) activities) as well as other outreach activities such as speeches, meetings, and participation in environmental events. With additional resources we propose conducting a number of education and outreach activities including holding regional workshops and conferences with other Regional Boards as well as experts in the field, contacting marina operators individually, and offering an incentives program.

Potential Long-term Activities

Arrundell Barranca: The Regional Board staff have been approached by the City of San Buenaventura for input on a potential project to re-route the Arrundell Barranca from Ventura Harbor to the Santa Clara River estuary. The proposal calls for a constructed wetlands near the estuary to treat the Barranca's water before entering the Santa Clara River. The project is proposed as a method of dealing with periodic coliform exceedances in areas of the Ventura Harbor/Ventura Keys.

Seawater Intrusion into the Oxnard Plain: The City of Oxnard is attempting to remove high TDS inputs to their treatment plant with the ultimate goal of reuse of the wastewater for a seawater intrusion barrier project in the Oxnard Plain.

Implementation of watershed-wide biological monitoring: This is a long-term goal for all of our watersheds.

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Section 3. Regionwide Activities

There are many activities conducted at the Region which do not apply to a specific watershed; instead they represent ongoing regionwide strategies and policies, or programs which are not directly linked to the rotating watershed cycle. Also, statutory, regulatory, or funding requirements may dictate completion of some activities at odd intervals throughout the five-year watershed cycle (such as increased emphasis on pretreatment inspections). We expect that some of these activities, which include triennial reviews, water quality assessment (305(b)) reports, updating lists of impaired waterbodies (e.g. the federal 303(d) list), can be negotiated into a watershed schedule (see Monitoring and Assessment discussion under each Watershed section for proposed water quality assessment scheduling). See Table 2 below for more examples of watershed versus non-watershed related activities.

Table 2. Example Work Activities and Their Fit (or not) Into Watershed

Watershed Tasks	*Non-Watershed Tasks*
Renew permits	Issue new permits
	Develop new general permits
Integrate municipal storm water program	Issue individual industrial and storm water permits
Conduct inspections for watershed permits	Conduct inspections on new permits
Enforcement (in-cycle compliance)	Enforcement (spills, out of cycle compliance)
Implement NPS controls	Develop regional strategies to address NPS problems
TMDL/WLAs	
Develop, coordinate and implement watershed monitoring	Coordinate monitoring on a regional scale
Water Quality Assessments (State of the Watershed Reports, partial updates to 305(b) by watershed)	Biennial 305(b) Reports to USEPA
Develop watershed policies	Develop regional policies
Watershed-specific Basin Plan Updates	Regional Basin Plan Updates, Triennial Reviews (as Currently required)
Data management (input and use by watershed)	Regional Database management (development and
GIS (input of watershed-specific layers and information)	GIS (development and input of regional layers and Maintenance of system)
Watershed-specific outreach/education	General outreach education
Incorporation of CEQA and 401 Decisions into watershed planning (as groups are formed, and as timing permits)	Timely review of CEQA documents, 401 certifications per statutory deadlines

And, while the Watershed Management Initiative strives to integrate and coordinate the various Regional and State Board programs and address the highest priority funding needs for those programs, there is also need to respond to and accommodate priorities established by the individual Regional and State Boards' members, priorities established prior to the WMI which run on their own timelines, or other new mandates which may affect the way the WMI is implemented in a Region. It is important to re-state here that the WMI is not a new program but rather a way to describe our approach to integrating existing and newly evolving programs and mandates. The following describes our overall approach to implementing a number of programs (some statewide mandates) and other Board priorities.

Core Regulatory

During FY01/02, we shall be carrying out regularly scheduled permit renewals in the Santa Clara River and Calleguas Creek Watersheds. The other activities we will be conducting for this one year are on a regionwide rather than watershed scale due to a number of factors.

One activity involves renewing both officially and unofficially backlogged permits. Many backlogs were created unofficially through utilizing our original seven- rather than five-year cycle for permit renewals. These should decrease greatly as we phase into a five-year cycle but, in the meantime, there will likely continue to be some backlog for FY01/02. We also plan to renew our general permits (see below) to incorporate Basin Plan amendments and fine-tune other requirements.

Another activity which has taken up considerable time, and contributed to backlogged permits, is responding to appeals and lawsuits. At issue for a number of permits is a lack of regional nutrient objectives which has translated into a lack of permit limitations and subsequent petitions and/or lawsuits. Ideally, TMDLs would be adopted in the year proceeding permit renewals for a particular watershed . Permit limitations could then be based on allocations from the TMDLs. Also ideally, we would have state-adopted water quality objectives (or an implementation plan for federal numbers) or ecologically-relevant regional objectives for parameters such as nitrogen and phosphorus to use for development of permit limitations. These "official" numbers will likely be available in the near future but, in the meantime, we continue to experience challenges to our permit limitations (or lack thereof).

Recently enacted legislation which does not allow Board discretion to issue Time Schedule Orders without penalties has added to the difficulty of adopting permits per original schedules.

One of the final tasks of the Bay Protection and Toxic Cleanup Program was adoption of a statewide Consolidated Plan for cleanup of toxic hot spots. Water Code Section 13395 states that the Regional Board is required to reevaluate WDRs including (1) an assessment of the WDRs that may influence the creation or further pollution of the known toxic hot spot; (2) an assessment of which WDRs need to be modified to improve environmental conditions at the known toxic hot spot; and (3) a schedule for completion of any WDR modifications deemed appropriate. We were required to begin the reevaluation of WDRs associated with high priority known toxic hot spots within 120 days after final approval of the Consolidated Plan (by March 15, 2000). As part of our reevaluation, we were required to submit a list of WDRs associated with each high priority toxic hot spot within six months after final approval of the Consolidated Plan (by May 15, 2000). The priority list for moderate and low priority known toxic hot spots must be submitted within one year of final approval of the Consolidated Plan (by November 15, 2000). While we do not have to actually revise any WDRs within these timeframes, if we find that we will need to make revisions, we will need to supply a schedule. And as we renew or modify WDRs, we need to include a finding that the discharge may contribute to the pollution present at the toxic hot spot.

Core Regulatory – General Permits

There are many dischargers in this Region covered by general permits for discharges to surface water through a letter issued by the Executive Officer. This activity occurs as often

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outside as within the watershed cycle. 40 CFR §122.28 provides for issuance of general permits to regulate a category of point sources if the sources:

a) Involve the same or substantially similar types of operations;

b) Discharge the same type of waste;

c) Require the same type of effluent limitations or operating conditions;

d) Require similar monitoring; and

e) Are more appropriately regulated under a general permit rather than individual permits.

General permits currently in effect include:

- NPDES Permit No. CAG914001 – for discharges of volatile organic compound contaminated groundwater to surface waters (threat/complexity rating 2B)
- NPDES Permit No. CAG994002 – for discharges of treated groundwater from construction and project dewatering to surface waters (threat/complexity rating 3B)
- NPDES Permit No. CAG994001 – for groundwater discharges from construction and project dewatering to surface waters (threat/complexity rating 3C)
- NPDES Permit No. CAG674001 – for discharges of hydrostatic test water to surface waters (threat/complexity rating 3C)
- NPDES Permit No. CAG834001 – for treated groundwater and other wastewaters from investigation and/or cleanup of petroleum fuel pollution to surface waters (threat/complexity rating 2B)
- NPDES Permit No. CAG994003 – for discharges of nonprocess wastewaters not requiring treatment systems to surface waters (threat/complexity rating 3C)

As a point of comparison, the highest threat/complexity rating is 1A and the lowest 3C.

Core Regulatory – Storm Water

Storm water activities include those involving the three municipal permits in the Region, facilities regulated under the State's general industrial permit, and construction sites regulated under the State's general construction permit.

Municipal permits

Municipal permits currently in effect include:

NPDES Permit No. CAS004003 – adopted in 1999 this is the permit for municipal storm water and urban runoff discharges within the city of Long Beach

NPDES Permit No. CAS004002 – adopted in 2000 this is the permit for municipal storm water and urban runoff discharges within the Ventura County Flood Control District, County of Ventura, and cities of Ventura County

NPDES Permit No. CAS614001 – adopted in 1996 this is the permit for municipal storm water and urban runoff discharges with the county of Los Angeles

An important part of the urban municipal permits (Los Angeles County and City of Long Beach) are the Standard Urban Storm Water Mitigation Plans (SUSMPs) and Numerical Design Standards for Best Management Practices (BMPs) which were adopted in 2000. The SUSMPs are designed to ensure that storm water pollution is addressed in one of the most effective ways possible, i.e., by incorporating BMPs in the design phase of new development and redevelopment. It provides for numerical design standards to ensure that storm water runoff is managed for water quality concerns in addition to flood protection and that pollutants carried by storm water are retained and not delivered to waterways.

Monitoring has indicated that mass emissions of pollutants to the ocean are significant from the urban watersheds such as the Los Angeles River, Ballona Creek, and Coyote Creek. Studies have found chemical concentrations of pollutants that exceed state and federal water quality criteria in storm drains flowing to the ocean and that there are adverse health impacts from swimming near them.

Municipal storm water regulations at 40CFR 122.26 require that pollutants in storm water be reduced to the maximum extent practicable (MEP). The definition of MEP has generally been applied to mean implementation of economically achievable management practices. Because storm water runoff rates can vary from storm to storm, the statistical probabilities of rainfall or runoff events become economically significant and are central to the control of pollutants through cost-effective BMPs.

The numerical design standard is that post-construction treatment BMPs be designed to mitigate (infiltrate or treat) storm water runoff from the first ¾ inch of rainfall, prior to its discharge to a storm water conveyance system. Other standards also apply; additional information on the SUSMP may be found on the Regional Board website http://www.swrcb.ca.gov/~rwqcb4. **Effective implementation of the SUSMP would be aided by 1 PY for review of city approvals of projects.**

Retail gasoline outlets (RGOs) were given a categorical exemption by State Board to the SUSMP requirements, partly because the threshold to mitigate developed by the Regional Board which was based on size and RGOs were deemed too small. **A needed special project (0.5 PY) is to develop a new threshold to mitigate for RGOs.**

The Ventura County Municipal Storm Water Permit co-permittees must implement an approved Ventura Countywide Stormwater Quality Urban Impact Mitigation Plan (SQUIMP) by 2001. The SQUIMP similarly addresses conditions and requirements for new development and significant redevelopment.

Industrial permit

The 1987 amendments to the Clean Water Act established a framework for regulating municipal and industrial storm water discharges under the NPDES Program. In 1990, the USEPA published final regulations that established application requirements for storm water permits. The regulations require that storm water associated with industrial activity that discharges either directly to surface waters or indirectly through municipal storm drains must be regulated by an NPDES permit.

State Board adopted the Industrial Activities Storm Water General Permit in 1997. The permit requires facility operators to (1) eliminate unauthorized nonstorm water discharges, (2) develop and implement a Storm Water Pollution Prevention Plan (SWPPP), and (3) perform monitoring of storm water discharges and authorized nonstorm water discharges. Facilities that discharge storm water associated with industrial activity requiring a General Permit are listed by category in the Code of Federal Regulations. These categories include manufacturing, mining/oil, recycling, steam electric generating, and light industry, among others. There are approximately 2,600 facilities in this Region covered by the general industrial permit. Most of these sites are in the Los Angeles River Watershed with the San Gabriel River Watershed and the Domiguez Channel and LA/LB Harbor WMA also containing a considerable number. **Five to ten additional PYs would be needed to fully address all aspects of industrial storm water permitting including compliance inspections of all facilities once every five years, review of SWPPPs, and followup work.**

Construction permit

In 1990, USEPA published final regulations that establish storm water permit application requirements for specified categories of industries. The regulations provide that discharges of storm water to waters of the United States from construction projects that encompass five or more acres of soil disturbance are effectively prohibited unless the discharge is in compliance with an NPDES permit.

State Board adopted a general permit for storm water discharges associated with construction activity in 1999. It contains narrative effluent limitations and requirements to implement appropriate Best Management Practices (BMPs) which emphasize source controls.

Elimination or reduction of nonstorm water discharges is a major goal of the general permit. It prohibits the discharge of materials other than storm water and authorized nonstorm water discharges. It also requires development of a Storm Water Pollution Prevention Plan (SWPPP) and monitoring program.

There is a total of 948 sites covered under the construction storm water permit as of November 2000. The majority of sites are in Ventura and western Los Angeles Counties with 310 in the Santa Clara River Watershed and 100 in the Calleguas Creek Watershed. There are a total of 307 residential sites of 10 acres or more in the Region compared to 112 sites of less than 10 acres. There are a total of 142 commercial sites of 10 acres or more while there are 104 sites of less than 10 acres.

Monitoring and Assessment

California Water Code Section 13192 required the SWRCB to assess and report on the State monitoring programs and to prepare a proposal for a comprehensive surface water quality monitoring program. As currently envisioned, the Surface Water Ambient Monitoring Program (SWAMP) will be implemented using a scientifically sound monitoring design with meaningful indicators of the environment and the results will be readily available to the public. Ambient monitoring serves as a measure of the overall quality of water resources and the overall effectiveness of Regional Boards prevention, regulatory, and remedial actions.

The SWAMP is intended to meet four goals:

1) Identify specific problems preventing the SWRCB, RWQCBs, and the public from realizing beneficial uses in targeted watersheds.

2) Create an ambient monitoring program that addresses all hydrologic units of the State using consistent and objective monitoring, sampling and analysis methods; consistent data quality assurance protocols; and centralized data management.

3) Document ambient water quality conditions in potentially clean and polluted areas.

4) Provide the data to evaluate the effectiveness of water quality regulatory programs in protecting beneficial uses of waters of the State.

Eventually, each of the SWRCB and RWQCBs existing monitoring programs (e.g., the State Mussel Watch Program, Toxic Substances Monitoring Program, toxicity studies, and fish/shellfish contamination studies) will be incorporated into SWAMP to ensure a coordinated approach without duplication.

Two general approaches are outlined in the current proposal for implementing SWAMP. One focuses on identifying specific problems in targeted watersheds (directed monitoring) through sampling in areas suspected to be contaminated or sampling to evaluate the status of the most sensitive beneficial use (e.g., sample frequently-consumed fish). The overall goal is to establish site-specific information in sites known or suspected to have water quality problems. Collecting information on locations which may need listing or delisting of waters under CWA Section 303(d) is a focus. The other approach involves documenting ambient water quality conditions in potentially clean and polluted areas (ambient monitoring). The overall goals is to develop a Statewide picture of the status and trends of the quality of California's water resources. It is intended that this portion of SWAMP will be implemented in each hydrologic unit of the State at least one time every five years. This portion of SWAMP is focused on collecting information on waters for which the State presently has little information and to determine the effects of diffuse sources of pollution.

Our general approach to implementing the SWAMP will be to sample in the preceding year those waters targeted under the WMI in the following year. For example, in FY00-01 we would sample in the Calleguas Creek and Santa Clara River Watersheds which are targeted under the WMI the following year. That way, each hydrologic unit in the Region would be sampled every five years. A possible exception to this approach is that we may investigate reference sites in non-targeted as well as targeted watersheds.

In general, we would utilize a stratified random approach to select sample sites (stratified to include areas around major confluences) except for our investigation into eutrophication which would utilize a uniform sampling approach and our followup work at previously identified problem sites. Depending on the number of samples deemed necessary (by the scientific review panel) in each stratum to give reliable results (and the associated costs), a more uniform sampling approach may be utilized instead, such as uniform sampling or sampling at confluences.

There is $360,000 available in FY00/01 for sampling and analysis. The majority (~60%) of those resources are anticipated to be dedicated toward biological monitoring as opposed to chemical analyses. Biological monitoring may include freshwater toxicity tests, habitat assessments, analysis of benthic invertebrates, fish bioassessments, or sediment toxicity tests. Much of this work will be conducted through a master contract with the Department of Fish & Game.

Basin Planning

Water Quality Legislation

The Porter-Cologne Water Quality Control Act (California Water Code) was enacted by the State in 1969 and became effective January 1, 1970. This legislation authorizes the State Board to adopt, review, and revise policies for all waters of the state and directs the Regional Boards to develop regional Basin Plans.

The Clean Water Act (CWA), enacted by the federal government in 1972, was designed to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. One of the national goals states that wherever attainable, water quality should provide for the protection and propagation of fish, shellfish, and wildlife, and provide for recreation in and on the water (i.e., fishable, swimmable). The CWA directs states to establish water quality standards for all "waters of the United States" and review and update such standards on a triennial basis.

The USEPA has delegated responsibility for implementation of portions of the CWA to the State and Regional Boards, including water quality planning and control programs such as the National Pollutant Discharge Elimination System (NPDES).

Besides state and federal laws, several court decisions provide guidance for basin planning. One decision reaffirmed the public trust doctrine, holding that the public trust is "an affirmation of the duty of the state to protect the people's common heritage in streams, lakes, marshlands, and tidelands, surrendering that right of protection only in rare cases when the abandonment of that right is consistent with the purposes of the trust." Public trust encompasses uses of water for commerce, navigation, fisheries, and recreation.

Basin Plans

Regional Board Basin Plans are designed to preserve and enhance water quality and protect the beneficial uses of all regional waters by providing consistent long-term standards and program guidance for the Region. Specifically, Basin Plans (i) designate beneficial uses for surface and ground waters, (ii) set narrative and numerical objectives that must be attained or maintained to protect the designated beneficial uses and conform to the state's antidegradation policy, and (iii) describe implementation programs to protect all waters in the Region. In addition, Basin Plan incorporate (by reference) all applicable State and Regional Board plans and policies and other pertinent water quality policies and regulations.

As part of the State's Continuing Planning Process, components of Basin Plans are reviewed as new data and information become available or as specific needs arise. Comprehensive updates of Basin Plans occur in response to state and federal legislative requirements and as funding becomes available. State Board and other governmental entities' (federal, state and local) plans, that can affect water quality, are incorporated into the planning process. Following adoption by Regional Boards, the Basin Plans and subsequent amendments are subject to approval by the State Board, the State Office of Administrative Law (OAL), and the United States Environmental Protection Agency (USEPA).

Recent Basin Plan Amendments

Basin Plan amendments will be completed periodically as new standards, policies, and other information are developed. TMDLs will also be adopted as Basin Plan amendments. This will generate a significant workload for Standards/TMDL staff over the next 13 years. We also anticipate that watershed efforts utilized, in part, to accomplish TMDLs will identify other possibilities for Basin Plan studies and amendments (e.g., new or revised standards, new policies).

The first TMDL was adopted by the Regional Board in 1999 (amended in 2000) to reduce trash on the East Fork of the San Gabriel River. This Basin Plan amendment has since been approved by the State Board, OAL and USEPA.

A Basin Plan amendment updating municipal and domestic water supply designations was brought to the Board for consideration in late 1998. In November 1998, the Regional Board voted to amend the Water Quality Control Plan for the Los Angeles Region (Basin Plan), by adopting a resolution to "Incorporate Changes in Beneficial Use Designations for Selected Waters." This amendment removed the beneficial use designation for "Municipal and Domestic Supply" (MUN) from eight surface waters and two ground water areas along the coast. The State Board voted to approve this amendment at the February 1999 Board hearing, however, in July 1999, the State Office of Administrative Law (OAL) issued a Notification of Disapproval due to a number of details including our responses to comments. The Regional Board resubmitted groundwater portion of the amendment, which was approved by OAL in 2000.

In 1990, the Regional Board adopted Resolution No. 90-004 (Drought Policy) which had a term of three years and provided interim relief to dischargers who experienced difficulty meeting chloride objectives because of a state-wide drought. The policy adjusted effluent limits to the lesser of 1) 250 mg/l or 2) the chloride concentration in the water supply plus 85 mg/l. In 1995, the Regional Board extended the interim limits for three years and directed staff to develop a long-term solution to deal with the impact of changing water supply, especially during droughts. In 1997, the Regional Board adopted Resolution No. 97-002 (Chloride Policy) which amended the Basin Plan by setting the chloride objective at 190 mg/l except in the Calleguas Creek and Santa Clara River Watersheds where, due to the great concern for protection of agriculture, staff were directed to determine the chloride concentrations sufficient to protect agricultural beneficial uses. The Chloride Policy has since been approved by the State Board and Office of Administrative Law (OAL).

Water Quality Objectives

The CWA (§303) requires states to develop water quality standards for all waters and to submit to the USEPA for approval all new or revised water quality standards are established for inland surface and ocean waters. Water quality standards consist of a combination of beneficial uses and water quality objectives, as well as an antidegradation policy. Water quality objectives may be expressed as either numeric limits or a narrative statement.

In addition to the federal mandate, the California Water Code (§13241) specifies that each Regional Board shall establish water quality objectives. The Water Code defines water quality objectives as "the allowable limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." Thus, water quality objectives are intended (i) to protect the public health and welfare and (ii) to maintain or enhance water quality in relation to the designated existing and potential beneficial uses of the water. Water quality objectives are achieved through Waste Discharge Requirements and other programs. These objectives, when compared with future water quality data, also provide the basis for identifying trends toward degradation or enhancement of regional waters.

Triennial Review Process

The California Water Code, (§13240), directs the State and Regional Boards to periodically review and update Basin Plans. Furthermore, the CWA (§303 [c]) directs states to review water quality standards every three years (triennial review) and, as appropriate, modify and adopt new standards.

In the Triennial Review Process, basin planning issues are formally identified and ranked during the public hearing process. These and other modifications to the Basin Plan are implemented through Basin Plan amendments as described below. In addition, the Regional Board can amend the Basin Plan as needed. Such amendments need not coincide with the Triennial Review Process.

The year 2000 triennial review is currently underway with the public hearing process scheduled for January or February 2001. While basin planning priorities have not yet been identified through the process, there are clearly some issues that will need time and resources in the upcoming years. Many of these issues have been raised due to EPA recommendations, new legislation and court orders. For example, in EPA's letter approving the Basin Plan, EPA identified 14 issues that should be included in the triennial review. These include: updating beneficial uses to better identify waterbodies supporting rare, threatened and endangered species, in particular; updating water quality objectives (e.g., ammonia and bacteria); and updating implementation policies and procedures (e.g., for acute and chronic toxicity objectives).

Another issue, driven by recent legislation, involves the Regional Board waiver policy. Regional Boards may issue both categorical and individual waivers. In the case of categorical waivers, the Regional Board must approve and issue categorical waiver criteria either through adopting a specific resolution or Basin Plan amendment. Once a categorical waiver is approved by the Regional Board, Regional Board staff may be delegated the responsibility to review and approve categorical waivers. Four categorical waivers have been approved in the Region, as set forth in Resolution No. 53-5 (adopted in 1953). These are: septic tanks, swimming pool discharges, on-site drilling mud discharges from single oil wells, and discharges from private impoundments or lakes. Individual waivers are typically for construction or development projects that are short-term or one-time events.

Section 13269, Paragraph (a), of the Water Code states that certain Water Code provisions "may be waived" by a Regional Board for a specific discharge or a specific type of discharge "if the waiver is not against the public interest." However, recent legislation (Senate Bill 390, amending Section 13269) requires that all waivers or waiver categories be evaluated and renewed every 5 years. Initially, Regional Boards must evaluate and renew all waivers and waiver categories by January 1, 2003, otherwise they will automatically terminate. After this initial evaluation and renewal, Regional Boards must conduct on-going compliance monitoring and renew, every 5 years, all waivers and waiver categories. The evaluation of waivers requires an initial review of all waivers and waiver categories, as well as validation of the adequacy of waiver conditions through field sampling at a representative number of discharges granted waivers. Depending on the data generated from this exercise, the Regional Board may decide to renew the waiver category (based on the adequacy of waiver conditions and their observance), amend the conditions (based on their inadequacy as documented through field tests), or allow the waiver category to automatically terminate on 1/1/2003 (based on the documented impact on water quality). If the last option is chosen, the Regional Board will then have to determine how those discharges should be regulated—either through general WDRs or individual WDRs.

Another issue of importance is the anticipated workload associated with adopting TMDLs as Basin Plan amendments on a very short time schedule, as required by the Consent Decree.

There are a number of triennial review issues from 1995 that have not been addressed. In addition, future triennial review issues may include:

- Development of biomonitoring/biocriteria efforts
- Further work on ensuring compliance with ammonia objectives by June 2002
- Implementation issues associated with the California Toxics Rule and State Implementation Policy
- Specific refinements to certain beneficial uses; conducting regular beneficial use assessments to provide more detail – particularly for aquatic life
- Development of regional and watershed-specific policies for nonpoint sources

Proposed (Needed) Near-term (FY 2001/02) and Long-term (beyond FY 2002/03) Resource Allocation for Standards and Planning Activities

Task	Product	Near-term (H,M, or L priority)	Long-term (H,M, or L priority)	PYs	Contract ($)
Implement triennial review tasks	various	H	M	3.0	
Amend Basin Plan for adopted TMDLs	Updated Basin Plan	H		2.0	
Address waiver policy	Updated waiver policy		H	0.5	
Update Basin Plan maps, including reach boundaries	Updated graphics in Basin Plan		M	1.0	
Prepare web-based version of Basin Plan	Interactive web version		M	0.5	
Review of CEQA documents	Comments to lead agencies during project planning and development	H		1.0	
Preparation of CEQA documents (as needed)	CEQA documents		M	0.2	

We will remain committed to involvement with the 205(j) grant program for planning and assessment activities. Table 3, which follows lists our priority projects under that grant program.

Table 3. Targeted Watersheds and Projects for 2001/02 Section 205(j) Grants in the Los Angeles Region

Watershed/ Waterbody	Project Description	Outcomes/ Products
Los Angeles River Watershed	Fund one component (bioassessment) of an overall watershed monitoring program; evaluate its usefulness in future watershed assessments and as an element in a watershed-wide monitoring program; establish baseline that can be used for comparison after implementation of control measures at pollutant sources (both point and nonpoint)	Additional assessment information for Year 2002 WQA; baseline beneficial use support information
Los Angeles River Watershed	Fund collection and assembly of <u>all</u> monitoring data for watershed including utilizing sources such as monitoring pledged in CEQA or 401 certification documents	Historic database (mapped sampling sites) as starting point for future work
Santa Monica Bay WMA	Prioritize storm drains needing diversion; focus efforts on major problem drains for coliform TMDL implementation	Ability to focus efforts on the major problem drains
Santa Monica Bay WMA	Fund portion of watershed-wide monitoring program in Malibu, with emphasis on nutrients and coliform or bioassessment concerns in the upper portion of the watershed as part of an integrated monitoring effort jointly undertaken by local stakeholders	Produce data for TMDLs; find sources of impairments; evaluate any BMPs being implemented; assess areas of watershed not previously studied
Calleguas Creek Watershed	Hydrologic model of watershed, including the lagoon	Hydrologic model (including Mugu Lagoon)
San Gabriel River Watershed	Fund collection and assembly of <u>all</u> monitoring data for watershed including utilizing sources such as monitoring pledged in CEQA or 401 certification documents	Historic database (mapped sampling sites) as starting point for future work
San Gabriel River Watershed	Fund collection of bioassessment data for watershed; evaluate its usefulness in future watershed assessments and as an element in a watershed-wide monitoring program; establish baseline that can be used for comparison after implementation of control measures at pollutant sources (both point and nonpoint)	Additional assessment information for Year 2002 WQA; baseline beneficial use support information
San Gabriel River Watershed	Hydrologic model of estuary (emphasis on establishing characteristics of fresh- and saltwater mixing zone)	Hydrologic model of estuary
San Gabriel River Watershed	Develop plan for maintenance of watershed's flood control dams.	Most effective method to clean out reservoirs without beneficial use impairments
Regionwide	Regional planning to remove septic tanks in densely populated areas and hook up to sewers	A plan to remove septics in densely populated areas and reduce inputs (coliforms and nutrients) to ground water and surface water from faulty septics and congested leachfields (a plan to implement coliform and nutrient TMDLs)

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Wetlands Protection and Management

Wetlands acres in the Region have diminished greatly over the past several decades as coastal development, in particular, has increased. Wetlands provide habitat, serve to slow down water flow, decrease total volume through infiltration, and filter out a number of pollutants through active uptake by plants as well as deposition in sediments. Wetlands such as coastal estuaries are a buffer zone between ocean and inland water resources and are heavily utilized by aquatic organisms. Continuous stretches of riparian habitat function as wildlife corridors to allow animal movement between increasingly isolated populations. They also serve as popular recreational destinations for residents and visitors. Unfortunately, many of our Region's wetlands are impacted by varying kinds and amounts of pollutants and alterations.

Over the past 7 years, we have embarked on a number of efforts to inventory and evaluate our Region's wetlands. These efforts have included the following:

- We funded a 1993 study, entitled *Waterbodies, Wetlands, and their Beneficial Uses in the Los Angeles Region* which provides descriptions, maps, photos, and functional values of wetlands throughout the region.

- Our Santa Monica Bay Restoration Project funded a wetlands inventory in 1993 which outlines historical changes in wetlands in the Santa Monica watershed, an inventory of current wetlands in the watershed, and potential restoration and creation projects in the watershed.

- The Regional Board continues the work of inventorying through participation in the Southern California Wetlands Recovery Project, which for the first phase effort, conducted an inventory of coastal wetlands from Santa Barbara to the U.S.-Mexico border. This inventory included information on twelve wetlands in seven watersheds for our region. When compared to estimated historical acreages, Los Angeles County has lost 93% of its wetlands while Ventura County has lost 58% of its wetlands.

  A 20-year regional wetland plan and strategy for prioritizing and restoring sites is being developed. Currently, the Project funds wetlands projects which involve planning, restoration, or acquisition. Some of the this region's wetlands given a high priority for funding include Los Cerritos Wetlands, Malibu Lagoon, Ormond Beach Wetlands, and the Ventura River estuary. More information about the Project may be found on its webpage at http:www.coastalconservancy.ca.gov/scwrp/index.html.

Water Quality Certification (401) Program

A key wetlands regulatory tool for the Regional Board is the CWA Section 401 Water Quality Certification Program which regulates discharges of dredge and fill materials to waters. The 401 certification program is one of the most effective tools the state has for regulating hydrologic modification projects, especially those which directly impact the region's diminishing acres of wetlands and riparian habitat. Program work is conducted in conjunction with U.S. Army Corps of Engineers and the California Department of Fish & Game.

Key program activities should include CEQA documents review/response (possibly involvement as lead agency), pre-construction meetings with applicants, site visits, application processing, follow-up monitoring and inspections, and enforcement. Unfortunately, the program is currently severely underfunded with only application processing being undertaken. **The program is currently funded at 2.1 PYs; the FY 00/01 statewide needs analysis for the 401 certification program indicated a needed augmentation of 13.9 PYs.** Any incremental increases in the baseline PYs would go first toward follow-up work and enforcement, then toward increased support of application processing, then coordination meetings, site visits, and CEQA documents review/response. Follow-up work is especially critical since mitigation wetlands often do not function as well as projected during the planning phase. Another very important activity that could be funded is the development of policies regarding in-stream gravel mining and use of in-stream sediment basins.

Furthermore, beginning in FY 00/01, the program began requiring in-house certification rather than sign-off by State Board. This has resulted in more detailed review of all projects, even those which would previously have been given less attention (those with little likelihood of producing impacts) with less time then being available for large projects likely to produce impacts. Another program change which occurred in the past fiscal year was allowing third-party petitions of certification decisions; previously, only the applicant was allowed to do this. This leads to potentially needing to divert scarce resources from application processing to litigation work.

Approximately 150-200 applications are processed each year. Information about projects and the program in general is available on the Regional Board website at http://www.swrcb.ca.gov/~rwqcb4/.

Recently, the Regional Board applied for USEPA wetlands protection grant funding under CWA Section 104(b)(3) for federal fiscal year 2001. The pre-proposal was competitive and the Board was asked to submit a full, detailed application. We are requesting $309,500 from USEPA to conduct a two-year study to access the effectiveness of wetlands mitigation conducted through the 401 certification program. Funds will be awarded during summer 2001.

Management of Nonpoint Source Pollution

Background

The Porter-Cologne Water Quality Control Act (Porter-Cologne), Division 7 of the California Water Code, establishes a comprehensive program for the protection of water quality and the beneficial uses of State waters. Porter-Cologne applies to both surface and ground waters, and to both point and nonpoint sources. The implementation portion of this comprehensive program should provide for the attainment of water quality standards.

The two primary federal statutes that establish a framework for addressing nonpoint source pollution in this Region are **Clean Water Act (CWA) Section 319** and the **Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 Section 6217**. Together these statutes encourage states to assess water quality problems associated with nonpoint sources of pollution and to develop programs to control these sources.

- CWA Section 319 requires that, in order to be eligible for federal funding, states develop an assessment report detailing the extent of nonpoint source pollution, and a management program specifying nonpoint source controls.

- CZARA Section 6217(a) requires the state to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters; establish coastal nonpoint source programs.

These programs will be implemented through changes to the state's current nonpoint source control program approved by USEPA under CWA Section 319 and through changes to the state's coastal zone management program (implemented in this state by the California Coastal Commission) approved by NOAA under Coastal Zone Management Act Section 306.

Under CZARA, California must (1) provide for the implementation of management measures that are in conformity with the USEPA *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (1993) and (2) provide a process for developing and revising management measures to be applied in critical coastal areas and in areas where necessary to attain and maintain water quality standards.

Management measures are defined in CZARA as: "economically achievable measures to control the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollution reduction achievable through application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other available alternatives." Mechanisms for implementation of these management measures may include, for example, permit programs, zoning, enforceable water quality standards, and general environmental laws and prohibitions by which a state exerts control over private and public lands and water uses and natural resources in the coastal zone (including those which may be implemented by agencies other than the State Water Resources Control Board and the California Coastal Commission). States may also use voluntary approaches like economic incentives if they are backed by appropriate regulations.

The State recently adopted an updated nonpoint source management plan which includes a 5-year implementation plan as well as a longer-term 15-year implementation strategy. The plan by USEPA and NOAA in July 2000. Implementation of the plan will entail the use of considerable resources at the Regional Board level. Documents relating to this plan may be found at http://www.swrcb.ca.gov/nps/html/protecting.html.

While it is clear nonpoint sources of pollution are difficult to manage, the state's current nonpoint source management plan (developed in 1988 pursuant to Clean Water Act Section 319) does present a three-tiered management approach which can be implemented sequentially or a focus may be put on one tier if deemed effective in a particular situation:

- **Tier 1**, self-determined implementation of best management practices (BMPs), acknowledges the advantages of property and business owners pursuing creation of site-specific or business-specific programs of waste management tailored to their budget.

- **Tier 2**, regulatory-based encouragement of BMPs, may occur when voluntary implementation is lacking. Encouragement may be effected through Regional Board waiving of waste discharge requirements if compliance with BMPs occurs. Or, BMPs may be enforced indirectly by entering into management agency agreements (MAAs) with agencies which have the authority to enforce. These MAAs would reference the specific BMPs to be used and the means of implementation.

- The Regional Board can adopt and enforce requirements on any waste discharge including those from nonpoint sources. **Tier 3** in the nonpoint source management hierarchy involves prescribing effluent limitations which would in turn require implementation of BMPs in order to insure compliance.

The State's Nonpoint Source Management Plan supports Regional Boards actively promoting voluntary implementation of BMPs but also supports that, when necessary, the Regional Boards exercise their regulatory authority over nonpoint sources in order to achieve water quality objectives. This Regional Board utilizes the full range of nonpoint source management options. A discussion of the overall approach to management of nonpoint source pollution used in this Region follows while specific nonpoint source issues and implementation activities relative to individual watersheds are described in the appropriate watershed section.

Proposition 13 Funding

The passage of the Costa-Machado Water Act of 2000 (Proposition 13) provided for the availability of water quality grants under three subaccounts: (1) Chapter 6, Article 2, Watershed Protection Program, (2) Chapter 7, Article 2, Nonpoint Source Pollution Control Program, and (3) Chapter 7, Article 5, Coastal Nonpoint Source Control Program.

The Watershed Protection Program provides funding for development of local watershed management plans as a priority and, additionally, funding for implementation of nonpoint source control projects that are consistent with local watershed plans and Regional Board water quality control plans. The Nonpoint Source Control and Coastal Nonpoint Source Control Programs provide funding for implementation of nonpoint source control projects that are consistent with local watershed plans and Regional Board water quality control plans.

There are more specific requirements for funding under each subaccount but all three include the a number of criteria be used in the project ranking and selection process. Criteria include (but are not limited to) that the project: consider the entire ecosystem for protection or restoration; address the root causes of degradation, rather than the symptoms, has definable targets and desired future conditions; and that the project helps protect intact or nearly intact ecosystems and watersheds.

Sixty percent of the funding is required to go to the six southern California counties. Funding levels are considerably higher than that available through CWA Section 319(h) and will be a critical component of nonpoint source work in this Region.

Our Approach

The State's Nonpoint Source Management Plan puts an emphasis on prioritization of nonpoint source categories as well as those waters impacted by nonpoint source pollution. It also states that management activities and implementation schedules needs are to be identified (e.g. monitoring for source identification, education, training, regulation, interagency agreements, and employment of BMPs). As is discussed elsewhere, many of these activities are severely underfunded. However, with that in mind, the following presents this Region's goals and objectives for the implementation of the State's Nonpoint Source Management Plan. Program objectives which apply most specifically to particular watersheds are highlighted and enlarged upon in the appropriate watershed section, as appropriate. The following program objectives will serve as a basis for workplan development; the final list of tasks will be dependent on the level of funding. The current funding level of these objectives are also included below and further described in Table 8.

Nonpoint Source Program Goals

Long-term Program Goal: improve water quality by implementing the management measures identified in the California Management Measures for Polluted Runoff Report (CAMMPR) by 2013

- Facilitate implementation of watershed management plans for prevention and control of nonpoint source pollution throughout the Region
- Expand our nonpoint source pollution control efforts in the Region
- Encourage more implementation of management measures in targeted watersheds
- Track implementation of management practices

Nonpoint Source Program Objectives

1) Program management – We shall oversee implementation of the Nonpoint Source Program in this Region through a variety of activities including fulfilling reporting requirements for the program, attending nonpoint source program roundtable meetings, and preparing and tracking annual workplan tasks. *Funded*

2) Contract management - In order to encourage planning and implementation of appropriate management measures, we shall explore funding opportunities and assume responsibility for administering and tracking contracts through which federal and state funds can be directed toward finding solutions to nonpoint source problems. Table 4 identifies our high priority projects for funding through the Section 319(h) grant program. Table 5 identifies our high priority projects for funding through Proposition 13 funding. (Note: high priority projects for funding through the 205(j) grant program are listed in Appendix 4.8). *Partially Funded*

3) Establishment of regional and/or watershed strategies – We intend to focus on developing regional (and where appropriate, watershed-specific) strategies to address nonpoint source pollution from agriculture (including investigation of use of nutrients, pesticides, and irrigation return water at large farming operations, nurseries and horse stables), urban (specifically new and existing development, golf courses and septic tanks, the latter will be focused on densely populated communities and areas where ground water is a source of drinking water), marinas and hydromodifications. *Partially funded*

4) Increase coordination of nonpoint source program with TMDLs through identification and reporting on the primary sources of nonpoint source pollutants with associated loadings; increase coordination of the nonpoint source program with the WMI. *Partially funded*

5) Identify and prioritize management measures to control NPS activities and promote implementation of these specific management measures to reduce or eliminate nonpoint source pollution problems throughout the Region (see Table 6 for summary of Regional NPS Problems by Management Measure Category). *Partially funded*

- For **agriculture**, high priority NPS/CZARA Management Measures include: a) for **traditional agriculture**, erosion and sediment control, nutrient management, pesticide management, irrigation water management, and education/outreach; for **horse stables**, management of wastewater and runoff from confined animal facilities, grazing management, and education/outreach; for **nurseries**, nutrient management, pesticide management, irrigation water management, and education/outreach.

- For **urban**, high priority NPS/CZARA Management Measures include: a) watershed protection and runoff from new and existing development, b) for **septic systems** new and operating onsite disposal systems, and c) for **golf courses** pollution prevention/education.

- For **marinas**, medium priority NPS/CZARA Management Measures include: control of solid wastes, fish wastes, liquid material, and petroleum; boat cleaning and maintenance; maintenance of sewage facilities; and public education.

- For **hydromodification management**, low-medium priority NPS/CZARA Management Measures include: channelization and channel modification; streambank and shoreline erosion control; and education/outreach.

- For **wetlands, riparian areas & vegetated treatment systems,** low-medium priority NPS/CZARA Management Measures include protection of wetlands and riparian areas, restoration of wetlands and riparian areas, and education/outreach.

6) Increase participation in public outreach and education activities through technology transfer, public presentations and preparation of education packages. We will participate on technical advisory committees, regional workshops, and agency meetings to promote implementation of nonpoint source management measures through. *Partially funded*

Table 7 describes our short-term program objectives as they relate to our long-term goals. Table 8 summarizes our proposed FY2001/02 activities (potential workplan activities), describes the current level of funding, and defines where and at what level additional funding is needed. **We anticipate needing an additional 14.0 PYs to accomplish these tasks which are necessary to implement the State's upgraded NPS Plan.** Any incremental increase in staff levels would go toward: 1) greater identification, education, and promotion of stakeholder involvement, 2) increased determination of the effectiveness of BMPs and Management Measures implemented, 3) establishment of a more effective policy to address pollutants from septic systems, confined animal facilities, mobile businesses, in-stream gravel mining, and agricultural runoff, and 4) quantification of the effectiveness of mitigation used to replace wetlands and riparian areas impacted by development.

Table 4. High Priority Projects for FY 2001/02 319(h) Funding

Project Number	Project Description	Geographic Area/Watershed (* denotes Category 1 Priority Watersheds)	NPS Management Measures (as listed in State's Nonpoint Source Management Plan)	Watershed Restoration Action Strategy
R4 - 1	Pilot projects: trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, or implementation of septic correction measures (NOT related to a NPDES permit). Leads to demonstration of effective ways to reduce loadings from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Los Angeles River Watershed*	3.4.B. 3.6.A. 1.B.	Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997
R4 - 2	Restore aquatic and riparian habitats; enhance recreational uses. Leads to protection and enhancement of beneficial uses	Los Angeles River Watershed*	6.B.	Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997
R4 - 3	Restore wetlands (Malibu, Topanga, and Trancas Lagoons). Leads to protection and restoration of beneficial uses	Santa Monica Bay WMA*	6.B.	Santa Monica Bay Restoration Project. *Santa Monica Bay Restoration Plan*, 1995.
R4 - 4	Pilot projects: trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, or implementation of septic correction measures (NOT related to a NPDES permit). Leads to demonstration of effective ways to reduce loadings from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments	Santa Monica Bay WMA*	3.4.B. 3.6.A. 1.B.	Santa Monica Bay Restoration Project. *Santa Monica Bay Restoration Plan*, 1995.
R4 – 5	Implement comprehensive erosion control projects, with expected demonstrable improvements, in previously identified top three problem subwatersheds in terms of sediment production. Leads to significant reduction in sediment and pesticide loads to Mugu Lagoon.	Calleguas Creek Watershed*	1.A. 1.G. 5.3.A.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.
R4 – 6	Habitat enhancement/ riparian restoration. Leads to restoration and protection of beneficial uses	Calleguas Creek Watershed*	6.B.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.
R4 – 7	Reduce nutrients, pesticides, and sediments in irrigation water that flows to surface water or infiltrates to ground water. Leads to implementation of measures needed to comply with TMDLs and de-list impairments.	Calleguas Creek Watershed*	1.C. 1.D. 1.F. 1.G.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.

Table 4. High Priority Projects for FY 2001/02 319(h) Funding

Project Number	Project Description	Geographic Area/Watershed (* denotes Category 1 Priority Watersheds)	NPS Management Measures (as listed in State's Nonpoint Source Management Plan)	Watershed Restoration Action Strategy
R4 – 8	Restore aquatic and riparian habitats; enhance recreational uses. Leads to protection and enhancement of beneficial uses.	San Gabriel River Watershed*	6.B.	California Regional Water Quality Control Board, Los Angeles Region. *East Fork San Gabriel River Litter TMDL*, 1999. Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997.
R4 – 9	Trash reduction projects in upper San Gabriel River; elsewhere in watershed, management of horse corral runoff, golf course irrigation water runoff, urban runoff, or implementation of septic correction measures (NOT related to a NPDES permit). Leads to trash reduction in upper San Gabriel River (implementation of trash TMDL).	San Gabriel River Watershed*	3.4.B., 3.6.A, 1.B	California Regional Water Quality Control Board, Los Angeles Region. *East Fork San Gabriel River Litter TMDL*, 1999. Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997.
R4 – 10	Restore aquatic and riparian habitats; enhance recreational uses.	Los Cerritos Channel/Alamitos Bay WMA*	6.B.	None
R4 – 11	Restore aquatic and riparian habitats; enhance recreational uses. Leads to protection and enhancement of beneficial uses.	Santa Clara River Watershed *	6.B.	Santa Clara River Enhancement and Management Plan Steering Committee. *Draft Santa Clara River Enhancement and Management Plan*. City of Santa Clarita. *Santa Clara River Corridor Plan*.
R4 – 12	GIS repository for watersheds of Region; use in TMDLs a high priority.	Regionwide		California Regional Water Quality Control Board, Los Angeles Region. *Watershed Management Initiative Chapter*, 2000.
R4 - 13	GIS repository for water and wetland mitigation data.	Regionwide		None

Table 5. High Priority Projects for FY 2001/02 Proposition 13 Funding

Project Number	Project Description	Geographic Area/Watershed (* denotes Category 1 Priority Watersheds)	NPS Management Measures (as listed in State's Nonpoint Source Management Plan)	Watershed Restoration Action Strategy
Watershed Protection Program				
R4 – 1	Finalize development of Watershed Management Plan	Santa Monica Bay WMA* (Topanga Creek Watershed)		
R4 – 2	Develop Watershed Management Plan	Los Cerritos Channel WMA*		
R4 – 3	Finalize development of Watershed Management Plan	Calleguas Creek Watershed *		
R4 – 4	Finalize development of Watershed Management Plan	San Gabriel River Watershed*		
R4 - 5	Finalize development of *Santa Clara River Enhancement and Management Plan*	Santa Clara River Watershed*		
R4 – 6	Finalize development of Watershed Management Plan	Los Angeles River Watershed*		
R4 – 7	Develop Watershed Management Plan	Dominguez Channel and LA/LB Harbor WMA*		
R4 – 8	Implement priority projects identified in the *Steelhead Trout Restoration and Recovery Plan*	Ventura River Watershed		Entrix, Inc. *Steelhead Trout Restoration and Recovery Plan*, 1997,
R4 – 9	Implement priority projects identified in the *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*	Calleguas Creek Watershed*	1.A. 1.G. 5.3.A.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.
R4 – 10	Implement priority projects identified in the *Santa Monica Bay Restoration Plan*	Santa Monica Bay WMA*	3.4.B. 3.6.A. 1.B.	Santa Monica Bay Restoration Project. *Santa Monica Bay Restoration Plan*, 1995.
R4 – 11	Implement priority restoration and enhancement projects identified by the Southern California Wetlands Recovery Project	Santa Monica Bay WMA* Ventura River Watershed Misc. Ventura Coastal WMA* Los Cerritos Channel WMA*	6.B.	Current fiscal year workplan adopted by Board of Governors
R4 - 12	Implement priority restoration projects identified in the draft *Watershed, Wetlands, and Riparian Restoration Plan* for Calleguas Creek	Calleguas Creek Watershed*	6.B.	draft *Watershed, Wetlands, and Riparian Restoration Plan* for Calleguas Creek

Table 5. High Priority Projects for FY 2001/02 Proposition 13 Funding

Nonpoint Source Pollution Control Program				
R4 - 12	Implement priority projects identified in the *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*	Calleguas Creek Watershed*	1.A. 1.G. 5.3.A.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.
R4 - 13	Trash reduction projects in upper San Gabriel River (implementation of trash TMDL); elsewhere in watershed, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, or implementation of septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not).	San Gabriel River Watershed*	3.4.B. 3.6.A 1.B	California Regional Water Quality Control Board, Los Angeles Region. *East Fork San Gabriel River Litter TMDL*, 1999. Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997.
R4 – 14	Reduce nutrients, pesticides, and sediments in irrigation water that flows to surface water or infiltrates to ground water. Leads to implementation of measures needed to comply with TMDLs and de-list impairments.	Calleguas Creek Watershed*	1.C. 1.D. 1.F. 1.G.	Natural Resources Conservation Service. *Calleguas Creek Watershed Erosion and Sediment Control Plan for Mugu Lagoon*, 1995.
R4 - 15	Trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, or implementation of septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Los Angeles River Watershed*	3.4.B. 3.6.A. 1.B.	California Regional Water Quality Control Board, Los Angeles Region. *East Fork San Gabriel River Litter TMDL*, 1999. Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997
R4 - 16	Trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, or implementation of septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Santa Monica Bay WMA**	3.4.B. 3.6.A. 1.B.	Santa Monica Bay Restoration Project. *Santa Monica Bay Restoration Plan*, 1995.

Table 5. High Priority Projects for FY 2001/02 Proposition 13 Funding

Coastal Nonpoint Source Control Program				
R4 - 17	Coastal-oriented trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, impacts from boating activities, or implementation of sewer collection system improvements or septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings to the coast from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Los Angeles River Watershed*	3.4.B. 3.6.A. 1.B.	Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997
R4 - 18	Coastal-oriented trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, impacts from boating activities, or implementation of sewer collection system improvements or septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings to the coast from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Santa Monica Bay WMA*	3.4.B. 3.6.A. 1.B.	Santa Monica Bay Restoration Project. *Santa Monica Bay Restoration Plan*, 1995.
R4 - 19	Coastal-oriented trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, impacts from boating activities, or implementation of sewer collection system improvements or septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings to the coast from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	San Gabriel River Watershed*	3.4.B. 3.6.A. 1.B.	California Regional Water Quality Control Board, Los Angeles Region. *East Fork San Gabriel River Litter TMDL*, 1999. Los Angeles-San Gabriel Rivers Watershed Council. *The Los Angeles-San Gabriel Watershed, an Integrated Vision of the Future*, 1997

Table 5. High Priority Projects for FY 2001/02 Proposition 13 Funding

R4 - 20	Coastal-oriented trash reduction, management of horse corral runoff, golf course irrigation water runoff, urban runoff, nursery runoff, impacts from boating activities, or implementation of sewer collection system improvements or septic correction measures (activities related to a stormwater permit ARE eligible: those related to other NPDES permits are not). Leads to demonstration of effective ways to reduce loadings to the coast from these constituents, mainly, trash, nutrients, and coliform, all of which are causing impairments.	Los Cerritos Channel WMA*	3.4.B 3.6.A. 1.B.	

R0026692

TABLE 6. REGIONAL NPS* PROBLEMS BY MANAGEMENT MEASURE CATEGORY

Watershed	Pollutants impairing or threatening Beneficial Uses arranged by Management Measure Category					
	Agriculture	Silviculture	Urban	Marinas & Recreational Boating	Hydromodification	Wetlands & Vegetated Treatment Systems
Calleguas Creek Watershed	nitrogen sediment toxicity siltation toxicity salts selenium historic pesticides chlorpyrifos		nitrogen sediment toxicity siltation toxicity mercury other metals historic pesticides chlorpyrifos PCBs trash		siltation	
Los Angeles River Watershed	nitrogen chlorpyrifos historic pest.		nitrogen chlorpyrifos historic pest. trash selenium other metals coliform PCBs oil VOCs			
Miscellaneous Ventura Coastal Waters WMA	sediment toxicity historic pesticides		sediment toxicity historic pesticides Coliform PCBs PAHs metals	Coliform PCBs PAHs metals TBT		
Santa Clara River Watershed	historic pesticides nitrogen salts		historic pesticides nitrogen coliform trash			
San Gabriel River Watershed	nitrogen coliform toxicity		nitrogen coliform toxicity PCBs trash arsenic mercury other metals chloride abnormal fish histology			

* Problems may be partially or fully due to NPS. Point sources may also be contributing to the problem.

R0026693

TABLE 6. REGIONAL NPS* PROBLEMS BY MANAGEMENT MEASURE CATEGORY (cont'd)

[redacted]	Pollutants Impairing or threatening Beneficial Uses arranged by Management Measure Category					
Watershed	Agriculture	Silviculture	Urban	Marinas & Recreational Boating	Hydromodification	Wetlands & Vegetated Treatment Systems
Santa Monica Bay WMA	coliform nitrogen		coliform nitrogen PCBs sediment toxicity benthic comm. effects toxicity PAHs arsenic mercury other metals hist. pesticides trash fish consumption advisory debris salts	coliform metals PCBs sediment toxicity benthic comm. effects toxicity PAHs TBT	exotic vegetation habitat alteration hydromodification reduced tidal flushing	reduced tidal flushing exotic vegetation
Dominguez Channel and LA/LB Harbors WMA			coliform sediment toxicity benthic comm. effects PCBs historic pesticides PAHs metals nitrogen trash	coliform sediment toxicity benthic comm. effects PCBs historic pesticides PAHs metals TBT		
Los Cerritos Channel and Alamitos Bay WMA			historic pesticides PCBs sediment toxicity PAHs metals nitrogen coliform			
Ventura River Watershed	eutroph. DDT selenium		eutroph. metals trash		diversions	Diversions

* Problems may be partially or fully due to NPS. Point sources may also be contributing to the problem.

TABLE 7 – SHORT TERM OBJECTIVES

This table lists our specific short-term (1-5 years) objectives and the long-term goals to which they are linked

Objectives	Program Goal that the Objective Fulfills	2000	2001	2002	2003	2004	Management Measures
NPS Program management	Goals 2 and 4	X	X	X	X	X	
319(h)/205(j) contract management	Goals 1, 2 and 3	X	X	X	X	X	
Identify Primary sources of NPS impacts to water quality	Goals 1 and 2	X					
Identify and Prioritize Management Measures for NPS activities	Goals 1 and 2	X					
Increase coordination of NPS program with TMDLs and WMI	Goals 1 and 2	X	X	X	X	X	
Establishment of regional/watershed strategies	Goals 1 and 2	X	X	X	X	X	3.1A
Coordinate with other regulatory agencies and stakeholders to control NPS	Goals 1, 2 and 3	X	X	X	X	X	
Increase participation in outreach, education, workshops, TACs	Goals 2 and 3	X	X	X	X	X	1G,3.6A,4.3A
Promote implementation of high priority Management Measures for Agriculture and Urban Areas	Goals 2 and 3	X	X	X	X	X	1A,1C,1D,1E,1F,1G, 3.4A,3.4B,3.6A
Promote implementation of medium and low priority Management Measures for Marina's, Hydromodifications and Wetland and Riparian Area	Goals 2, 3 and 4	X		X	X	X	4.2A,4.2B,4.2C,4.2D, 4.2E,4.2F,4.3A 5.1.A,5.1.B,5.3.A, 5.4A, 6.0A, 6.0B, 6.0C

Long-Term Goal: Improve water quality by implementing Management Measures by 2013

- Program Goal 1: Facilitate implementation of watershed management plans for prevention and control of nonpoint source pollution throughout the Region
- Program Goal 2: Expand our nonpoint source pollution control efforts in the Region
- Program Goal 3: Encourage more implementation of Management Measures in targeted watersheds
- Program Goal 4: Track implementation of management practices

TABLE 8: PROPOSED SFY 2001/02 RESOURCE ALLOCATION

Task	Product	Management Measure(s)	Staff or Contract	Cost
NPS Program management	Annual Reports, Identify primary NPS impacts and prioritize management measures to control NPS activities		0.7	70,000
319(h)/205(j) contract management	Database to track projects & develop report summary, Contract QA/QC, Contract outreach		**0.7** 1.0	**70,000** 100,000
Increase coordination of NPS program with TMDLs and WMI	Better coordination of projects and increased participation in TMDL development and implementation		**0.1** 0.5	**10,000** 50,000
Establishment of regional/watershed strategies	Coordinated planning		0.2	20,000
Coordinate with other regulatory agencies and stakeholders to control NPS	Increase participation in outreach, education, workshops, TACs	1G,3.6A,4.3A, 5.4A, 6D	0.2 0.5	**20,000** 50,000
Promote implementation of high priority Management Measures for Agriculture And Urban Areas	Reduction of NPS impacts, summary of BMP's implemented, Enforcement of Non-compliance	1A, 1B,1C,1D,1E, 1F,1G,3.1A, 3.1B, 3.1C, 3.2A, 3.2B, 3.3A, 3.4A, 3.4B, 3.6A,	**0.9** 7.5	**90,000** 750,000
Promote implementation of medium and low priority Management Measures for Marina's, hydromodifi-cations, and wetland and riparian areas	Develop database to track projects and expand GIS system to confirmation project & mitigation locations	4.1A,4.2A,4.2B, 4.2C,4.2D,4.2E, 4.2F,4.3A,5.1A, 5.1.B,5.3.A, 5.4A, 6A, 6B, 6D	**0.1** 3.0	**10,000** 300,000
Coordinated planning	CEQA Review for watershed Management & large or regional projects	3.1A, 3.1B, 5.1B, 6A	1.5	150,000
Total funded staff Total unfunded staff			**2.9PYs** 14	**290,000** 1,400,000

STAFF COST ≥ 1 PY $100,000 (costs in **bold** are those with anticipated resources; costs not in bold are those currently without resources). Contract costs are for the entire contract even if multi-year.

Regional Board Enforcement Strategy

The statewide Water Quality Enforcement Policy adopted by State Board in 1996 is intended to make all enforcement consistent, predictable, and fair throughout the state. On March 3, 1997, the Regional Board adopted Resolution No. 97-005 which confirmed the Board's desire to carry out enforcement in a manner consistent with State Board's enforcement policy and that Regional Board staff prepare a regional enforcement strategy consistent with State Board's enforcement policy. The Resolution directed staff to implement the Regional Enforcement Strategy. The statewide enforcement policy is currently in the process of being revised.

The statewide Water Quality Enforcement Policy upon which the Region Board Enforcement Strategy is based states that "(v)iolations of Waste Discharge Requirements (WDRs) or applicable statutory or regulatory requirements should result in a prompt enforcement response against the discharger. At a minimum, the Regional Board staff must bring the following to the attention of their Regional Board for possible enforcement action:" effluent limit violations/other permit violations - major dischargers; effluent limit violations/other permit violations - other NPDES/WDR dischargers; toxicity violations - all NPDES dischargers; violations of compliance schedules and enforcement orders - all dischargers; failure to submit reports/deficient reports (excluding stormwater); violations of POTW pretreatment programs; stormwater permit violations/deficiencies/failure to submit reports; other violations and enforcement actions; and spills (generally, non-permittees).

Board staff are also involved in a number of interagency environmental task/strike forces including the U.S.E.P.A. Environmental Strike Force, Los Angeles County Strike Force, Ventura County Strike Force, and Santa Monica Mountains Task Force.

Data Management And GIS

The State Water Information Management system (SWIM) is an organizational-wide database that was designed to facilitate electronic reporting, tracking, and analysis of regional data and information. The two modules that have been developed so far have incorporated the core structure of the Waste Discharger System (WDS) and information for the Underground Investigations (UGI). The modular structure of the database allows inclusion of new programs without redesigning the data model. WDS has now been shut down and converted statewide to SWIM. We continue to develop and pilot new models and tools. Currently under development is a query by address tool, expanded ad-hoc query tool, and environmental data entry and retrieval tools.

SWIM now tracks information on permits, both NPDES and non-NPDES. This module expands the old database in several ways. We can now record the permit limits and can perform compliance checking of electronic data against these limits. Data submitted electronically are also available for evaluation by region or watershed or through a number of other filters. Data is also available for historic permits. Previously only data from the current fiscal year was online.

The Underground Investigations (UGI) module is a replacement for Region 4's Well Investigation Program (WIP) database. This module tracks the progress of WIP facilities, and provides reports to USEPA. This module could be expanded to track the progress of facilities in other programs such as Above Ground Tanks, Department of Defense, or Spills, Leaks, Investigation, and Cleanup should the need arise. This module could also be expanded to evaluate groundwater treatment methods, to track contaminants spatially, and to tie into Region 4's geographic information system (GIS).

The new database is Windows-based and uses pull-down menus to ensure consistency of data.

This past year we took the first steps to move our GIS from a limited "special project" oriented tool to a region- and program-wide standard tool. These steps include making Arcview available to all staff, having all coverages converted to standard projection and "served" from a central location, and developing custom interfaces for the UGT, WIP, and TMDL programs.

Over time, we expect to expand the capabilities of the system, by 1) adding new components to the system, 2) linking the data to geographic layers, 3) linking our system with others such as USEPA and 4) providing access by the public to certain information.

Specific needs include:

- A tool to search the entire database by address (currently under development)
- GIS connectivity with our database, to allow analysis of data using our GIS. This would facilitate watershed management
- Update coordinate fields in SWIM (to develop coverages, such as facility and sampling locations)
- Obtain additional GIS coverages, such as elevation contours, hydrogeologic basins, wetlands, land use
- Develop coverages to be available on the internet
- Develop a catalog of available maps
- Add a module to track 401 Certification application tracking and compliance
- Add a module to track CEQA documents
- Develop tools to perform TMDL analysis
- Internet connectivity, to allow the dischargers, other agencies, and the public to query the database
- A module to facilitate the input and storage of volunteer monitoring data
- Ability to scan in permits and reports and make them available electronically over the LAN and the internet
- Input information from other programs, such as SLIC, DOD and Underground Tanks
- Insure data compatibility with Southern California Coastal Water Research Project (SCCWRP) data

An estimate of minimum staff needs to coordinate this increased effort is 2 PYs/year. This would increase in future years as more demands are placed on our system. Significant contract dollars would also be needed. Exact costs are not available at this time.

Other Region-wide Activities

Other activities may be undertaken at odd intervals during the watershed cycle. These include, among others, processing applications for new permits, reviewing CEQA and NEPA documents, reviewing and commenting on requests for Section 401 water quality certification, landfill regulation, site (including DOD/DOE) cleanups, well investigation program activities, leaking underground storage tank cleanups, routine public outreach, and responding to spills, complaints (unrelated to permits), and special requests from the Regional Board (Table 2). Some of the other region-wide strategies and programs the Regional Board implements are described in more detail below.

BEACHES/COASTAL WATERSHED ACTIVITIES

This Region's coastal resources support many of our most valuable beneficial uses. Our beaches, from Ventura through Zuma, Malibu, Venice and Long Beach are world-renowned. The Region's coastal estuaries, dunes, and wetlands are nearly gone and what is left are highly degraded. These resources, while inherently valuable as natural resources, also have a high economic value to the State with many vacationers naming beaches and lakes as their prime vacation destination. These beaches and coastal resources are a huge tourist dollar generator.

Concurrently, our Region's ports and marinas are support valuable beneficial uses providing important avenues of trade as well as recreational boating opportunities and marine habitat. They too are impacted by the need to dredge and dispose of sediments often contaminated by upstream watershed sources.

It is clear the impacts to beaches, bays, coastal wetlands and estuaries, and near shore waters is especially critical to address from both an economic and ecological perspective. The Regional Board is focussing on protecting these resources through a combination of integrated coastal planning with an aggressive effort to assess and control watershed loadings of key pollutants - pathogens, trash and sediment (particularly contaminated) - which continue to degrade coastal areas and increase the costs of dredging. Also part of this effort will be a WEBsite which will provide access to "realtime" pathogen data for our beaches. These efforts are described in greater detail under individual watersheds. As funding is located for these issues, they will be coordinated Beaches/Coastal Watersheds activities. Specific elements that have funding are described below.

Contaminated Sediment Long-term Management Strategy

The Los Angeles County's coastline includes two of the nation's largest commercial ports and several major marina complexes and small-vessel harbors. Maintenance of authorized depths in existing channels and berthing areas and expansion and modernization of ports, harbors, and marinas, requires periodic dredging in virtually all of these facilities. Some of the sediments dredged from these harbors contain elevated levels of heavy metals, pesticides, and other contaminants. In most cases, the concentrations of these contaminants do not approach hazardous levels. However, the sediments contain enough contaminants that they are not suitable for unconfined ocean disposal. Additionally, the State's Bay Protection and Toxic Cleanup Program has identified bays and estuaries containing areas with contaminated sediments. Remediation of these sites may require dredging and disposal of this material. Disposal of any contaminated dredged materials requires special management, such as placement in a confined aquatic disposal site, capping, or disposal in an upland site. Additionally, some ports and harbors have considered other management techniques, such as treatment and beneficial re-use.

Recently, the ports and harbors have delayed or canceled several dredging projects because of contaminated sediment issues. The regulatory agencies evaluated disposal options for these projects on a case-by-case basis without the benefit of a regional perspective on management alternatives, cumulative impacts, and long-term solutions to prevent re-contamination of sediment. This approach has led to public concern over the ecological and human health implications of contaminated dredged material disposal. To resolve these issues, the regulatory and resource agencies, ports and harbors, environmental groups, and other interested parties agreed to establish a task force. The mission of the Contaminated Sediment Task Force (CSTF) is to prepare a Contaminated Sediment Long-Term Management Strategy (Strategy) for the Los Angeles region (limited to Los Angeles County). Past projects suggest that the major sources of contaminated dredge material will continue to be Marina del Rey Harbor, the ports of Los Angeles and Long Beach, and the mouth of the Los Angeles River.

The members of the CSTF agreed that the Strategy will consider confined aquatic and upland disposal, sediment treatment, beneficial re-use, other management techniques, and contamination source control. The CSTF agreed on a number of goals including identifying the scope of the contaminated sediment problem, an analysis of management and disposal alternatives, development of a unified regulatory approach, and identify inputs of contaminants to coastal waters and ongoing regional efforts to reduce such inputs with a view towards promoting efforts that would reduce the inflow of contaminants. Initially, the CSTF will work with existing watershed management programs.

The CSTF was established through a Memorandum of Understanding (MOU) among the state and federal agencies with regulatory jurisdiction over dredging and disposal activities, as identified by SB 673, and other agencies representing ports, harbors, and marinas. The following agencies are signatory to that MOU: U.S. Army Corps of Engineers; U.S. Environmental Protection Agency; California Coastal Commission; Regional Water Quality Control Board, Los Angeles Region; County of Los Angeles Department of Beaches and Harbors; City of Long Beach; Port of Long Beach; and Port of Los Angeles.

The CSTF will carry out its operation by two main committees (Executive and Management Committees), and five strategy development committees (Watershed Management and Source Reduction, Aquatic Disposal and Dredging Operations, Upland and Beneficial Re-use, Sediment Screening Thresholds, and Implementation Committees). The membership of the Management Committee includes those parties that signed the MOU and one organization selected to represent the environmental community (Heal the Bay). This committee is the main decision-making group with the CSTF. The Executive Committee consists of the chief executives of the four major agencies that regulate and manage dredging and disposal in Southern California. This committee will facilitate final agency concurrence, adoption, and implementation of the completed strategy. The strategy development committees will develop specific elements of the long-term management plan.

The CSTF has developed and is implementing an Interim Dredge Material Management Plan , and is required to complete the Contaminated Sediment Long-Term Management Strategy by January 1, 2003. The program is funded at the Regional Board and the Coastal Commission at 1 PY each per year over a five-year time period. The CSTF received $2,033,000 from the legislature to conduct studies to answer specific questions and fill data gaps necessary to allow completion of the long-term management plan.

The CSTF has a web site which may be consulted for additional information: http://www.ceres.ca.gov/coastalcomm/sediment/sdindex.html.

Regional Monitoring of Ocean Waters

The Southern California Bight Pilot Project conducted a survey in 1994 to assess the spatial extent and magnitude of ecological disturbances on the mainland shelf between Point Conception in Central California to the California-Mexico border. The survey was a cooperative effort between four large discharger agencies (City of Los Angeles, County Sanitation Districts of Los Angeles County, Orange County Sanitation District, and City of San Diego), regulators (U.S. Environmental Protection Agency, State Water Resources Control Board, and Los Angeles, Santa Ana, and San Diego Regional Water Quality Control Boards), as well as the Southern California Coastal Water Research Project, and the Santa Monica Bay Restoration Project. Monitoring focused on benthic infauna, sediment chemistry, sediment toxicity, demersal fish/invertebrate populations (trawling), water quality (CTD measurements), and bioaccumulation (fish tissue with species not consumed by humans). Final reports were published in 1998.

The Santa Monica Bay Restoration Project has developed a conceptual framework for ecosystem monitoring within Santa Monica Bay. Some components of this framework are being utilized. In1995, a regional sampling program was implemented for bacteriological monitoring at shoreline and inshore stations with high recreational use within the bay (a cooperative effort by City of Los Angeles, County Sanitation Districts of Los Angeles County, and Los Angeles County Department of Health Services).

Work on a regional sampling program to assess the loadings of contaminants entering the bay is also continuing. In the meantime, the Southern California Coastal Water Research Project (SCWRP) is working on a model POTW monitoring program for the four largest southern California dischargers (City of Los Angeles, Los Angeles County Sanitation Districts, Orange County Sanitation District, and City of San Diego) which will be available in 2000.

A second regional survey of the Southern California Bight was conducted in 1998. Rather than simply repeating the 1994 survey, the participants in the 1998 survey agreed to expand the monitoring program to include a larger geographic scope (including enclosed bays, harbors and estuaries, the Mexican coastline south of California, and offshore channel islands), new monitoring components (microbiology, greater emphasis on stormwater runoff impacts) and additional participants (small point source dischargers, stormwater groups and other interested parties, including volunteer monitoring programs being implemented by environmental organizations). Most of the sampling occurred over a six-week period from late July to early September, although certain components (water quality, microbiology) were performed during different time periods. Sampling of benthic infauna and sediment chemistry took place at approximately 250 stations, sediment toxicity at approximately 200 stations, and demersal fish/invertebrate populations and bioaccumulation at approximately 175 stations. The microbiology sampling was conducted at approximately 250 stations once per week over a 5-week period in August-September 1998 (dry season) and February-March 1999 (wet season). The water quality component included sampling once during dry weather (September-October) and twice during wet weather along several transect lines throughout the Bight.

As the monitoring data becomes available, it will be analyzed and discussed by the subcommittees and Steering Committee of the Bight'98 project, which include representatives from the participating agencies. Final reports are published as the data analysis is completed. The final reports for the microbiology studies have been released; other reports should come out in 2001 (e.g., toxicity, demersal fish/macroinvertebrate abundance, sediment chemistry, benthic infaunal communities and bioaccumulation) due to the longer time period required to analyze these types of samples. More information about the Bight and other related projects may be found on the SCWRP webpage http://www.sccwrp.org/.

USEPA's Environmental Monitoring and Assessment Program (EMAP) first visited the Bight to conduct regional monitoring in 1994, contributing to the funding of the Southern California Bight Pilot Project. However, EMAP was unable to provide funding for the Bight'98 survey. Planning is underway to conduct another bight-wide regional survey in 2002 and EMAP is planning to participate in this effort.

Coastal Ambient Monitoring Program (CAMP)/Seafood Monitoring

Governor Wilson's Executive Order W-162-97 (issued October 8, 1997) required Cal/EPA to inventory existing ocean and coastal water quality monitoring programs and make recommendations for a comprehensive program for monitoring water quality and reducing pollution within coastal watersheds, bays, estuaries, lagoons and nearshore ocean waters. The State Water Resources Control Board was assigned the responsibility to implement this mandate (funded by AB 1581 and AB 1429). SB 753 required the SWRCB to establish a statewide monitoring program to assess human health risks associated with recreational fishing and seafood consumption (Coastal Fish Contamination Study). A screening study was initiated during 1999 to assess approximately ten sites and supplement the information already available for Santa Monica Bay. However, oceanic conditions associated with an El Nino event precluded adequate collection of fish samples during 1999, so the screening study was extended into 2000 The goal is to develop a regional (Region 4 coastline, not just Santa Monica Bay) sampling program during 2001, which will probably keep most of the original framework created by the Bay Restoration Project, but expand it throughout the region. An inventory of coastal water quality monitoring programs has been prepared for Southern California with the assistance of SCCWRP; it can be accessed at: http://www.sfei.org/camp.

Other Regional Monitoring Programs (SMW/TSMP and BPCTP)

State Mussel Watch/Toxic Substances Monitoring Programs (SMW/TSMP): Water column monitoring for toxic substances can be unreliable since toxic substances are often transported intermittently and can be missed with standard "grab" sampling of water. In addition, harmful levels of toxicants are often present in such low concentrations that detecting them can be difficult and expensive. In some cases, a more realistic and cost-effective approach is to test the flesh of fish and other aquatic organisms that bioaccumulate these compounds in their tissues and concentrate toxicants through the food web.

In 1977, two biomonitoring programs were initiated by State Board: the Toxic Substances Monitoring and State Mussel Watch Programs. The Los Angeles Region is active in both programs which are implemented jointly by the State Board and the California Department of Fish and Game. Tissue samples collected under the TSMP are usually fish but can also include benthic invertebrates. The tissue is analyzed for trace metals and synthetic organic chemicals. The fish are generally collected from inland fresh waters but are occasionally collected from estuaries. The SMWP provides similar documentation of the quality of coastal marine and estuarine waters. Mussels, which are sessile (attached) bivalve invertebrates, serve as indicator organisms and provide a localized measurement of water quality, as they accumulate trace metals and synthetic organic chemicals in their tissues. Mussels are generally transplanted into the test site from "clean" areas of the state (generally Bodega Bay) although occasionally local, "resident" mussels are collected. Other types of shellfish can be used at times and sediments have, at times, been collected. The focus of TSMP sampling in the region has tended to be trend monitoring while the SMWP has been used more for "hot spot" identification although with lesser resources available in recent years, the SMWP has moved away from hot spot identification in favor of long-term trend monitoring at fewer sites in recent years. Data from these two programs have been critical in determining beneficial use impairments in coastal waters.

For FY00/01, the SWMP will seek to maintain a number of "long-term" sites in the LA/LB Harbor area as well as along the open coast in Santa Monica Bay . The TSMP will look toward evaluating targeted watersheds for this fiscal year, namely, the San Gabriel River (mostly in the estuary) and the Los Cerritos Channel Watershed.

Bay Protection and Toxic Cleanup Program (BPTCP): In 1989, state legislation added Sections 13390 through 13396 to the California Water Code which established the BPTCP. The program has four main goals: 1) to provide protection of existing and future beneficial uses of bays and estuarine waters, 2) to identify and characterize toxic hot spots, 3) to plan for cleanup or other mitigating actions of toxic hot spots, and 4) to develop effective strategies to control toxic pollutants, abate existing sources of toxicity, and prevent new sources of toxicity.

While in its identification and characterization phase, the program implemented regional monitoring at each of the coastal Regions. Sediment toxicity tests, chemical analyses, and benthic community surveys were used to classify each bay or estuarine waterbody. Waters were generally "pre-screened" for contamination using toxicity tests; if enough was found, more intensive monitoring followed to confirm the existence and spatial extent of monitoring. Using this approach, the Santa Monica Bay/Palos Verdes Shelf, parts of, Consolidated Slip/Dominguez Channel, Cabrillo Pier, Mugu Lagoon/Calleguas Creek, McGrath Lake, Los Angeles River Estuary, Marina Del Rey, and Marina Del Rey Entrance Channel were identified as candidate toxic hot spots. A number of other waters were identified as sites of concern.

State Board adopted a statewide, consolidated cleanup plan in June 1999 with Office of Administrative approval following in November 1999. Regional cleanup plans deal specifically with high priority candidate toxic hot spots; detailed cleanup plans were not required for moderate priority candidate toxic hot spots or sites of concern although listed in the document. Identified remediation/cleanup alternatives for toxic hot spots range from specific actions such as in-site capping, issuing waste discharge requirements, or dredging to more regional/watershed activities such as long-term management of contaminated sediments or proactive application of the watershed management approach as a preventive measure. At this point, no specific funding source has been identified to pay for remediation activities although potential funding mechanisms are addressed in the statewide consolidated cleanup plan. The best chance for obtaining funds for cleanup appears to be through the use of Supplemental Environmental Projects (SEPs) from enforcement actions or by partnering with other groups within the context of the watershed management approach to take advantage of local efforts. Funding for staff resources ended in June 1999.

Now that the Consolidated Plan has been approved, the Regional Board is required to reevaluate WDRs in compliance with Water Code Section 13395. The reevaluation shall consist of (1) an assessment of the WDRs that may influence the creation or further pollution of the known toxic hot spot; (2) an assessment of which WDRs need to be modified to improve environmental conditions at the known toxic hot spot; and (3) a schedule for completion of any WDR modifications deemed appropriate. We were required to begin the reevaluation of WDRs associated with high priority known toxic hot spots (i.e., Palos Verdes Shelf, Consolidated Slip, Cabrillo Beach, Mugu Lagoon, McGrath Lake) within 120 days after final approval of the Consolidated Plan (i.e., by March 15, 2000). As part of this reevaluation, we were required to develop a list of the WDRs associated with each high priority toxic hot spot (within six months after final approval of the Consolidated Plan (i.e., by May 15, 2000). The priority list for moderate and low priority known toxic hot spots (i.e., Ballona Creek Entrance Channel, Marina del Rey, Los Angeles River Estuary) must be developed within one year of final approval of the Consolidated Plan (i.e., by November 15, 2000). We do not have to actually revise any WDRs within these timeframes, but if we find that we will need to make revisions, we will need to supply a schedule. And as we renew or modify WDRs, we need to include a finding that the discharge may contribute to the pollution present at the toxic hot spot.

The program also has a website which may be consulted for additional information: http://www.swrcb.ca.gov/bptcp.

Funding Needs For Non-TMDL Programs (Watershed and Regionwide Activities)

This table presents resource needs (FY01/02) which are non-TMDL-related for watershed and regionwide activities. TMDL resource needs are described later in this section of the document.

Water-shed	Monitoring/ Special studies/ data handling	WQA	Standards/ planning	NPDES	Storm-water	Non-Chapter 15	NPS strategy imple-mentation	Wet-lands	TOTAL (PYs)	Con-tracts ($)
Santa Clara River	0.2	0.3	0.7	1.2	1.0	0.75	1.8	1.8	7.75	45,000
Calle-guas Creek	0.3	0.4	0.5	1.1	0.7	0.65	1.8	1.6	7.05	10,000
Domin-guez Ch. & LA/LB Harbor	0.3	0.75	0.2	0.8	1.2	0.5	1.0	1.3	5.3	--
Santa Monica Bay	0.2	---	0.5	5.2	2.0	3.0	1.8	1.4	14.1	210,000
Los Angeles River	0.3	--	0.5	1.4	1.9	0.5	1.8	1.5	7.9	220,000
San Gabriel River	0.3	—	0.5	1.9	1.9	0.5	1.8	1.4	8.3	25,000
Los Cerritos	0.1	—	0.2	0.2	0.3	0.1	0.9	1.3	3.1	—
Channel Islands	—	—	0.1	0.1	—	0.1	0.1	—	0.4	—
Ventura River	0.1	0.2	0.2	0.4	0.3	0.1	1.0	1.4	3.7	—
Misc. Ventura Coastal	0.2	0.3	0.2	0.7	0.7	0.3	1.0	1.3	4.7	$10,000
Region-wide	—	—	0.4	--	—	0.5	1.2	0.9	3.0	200,000

TMDL Scheduling And Development

Table 7 (in Appendix 4.7) shows 303(d) listed waterbodies/reaches by watershed. Clearly, there are a large number of waters in the Region which are impaired by a number of constituents (764 individual impairments were listed in the submittal to State Board). The overriding problem associated with TMDL development needs to be reiterated here, namely, staff resources at the Regional Board to either directly conduct or be involved in stakeholder-

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led TMDL investigations and in general stay dedicated to nonpoint source activities are still minimal. Specific TMDL resource needs for the next three fiscal years are defined in the resource planning matrix in the next section of this document. **In general, depending on the watershed, it is anticipated that 0.5 -2.0 PYs/watershed more will be needed** at a minimum to make additional headway on TMDLs and implementation of our nonpoint source strategy (as well as augment point source regulation, where needed); this need will increase as we add more TMDLs in the next two years to fully accomplish our TMDL mandate. Additionally, AB1740 (Ducheny) was enacted in 2000 and requires that to the extent interest is expressed by the public, and resources are available, each regional Board shall establish for each watershed where a water body is listed as impaired, an Advisory Committee consisting of the public and interested stakeholders who wish to be involved in the process of adoption and implementation of the corrective actions necessary to eliminate the impairment.

However, with a seemingly impossible workload before us, there is a reasonable and logical way to collapse or group TMDLs to make the most effective use of resources we currently have and any which we may obtain in the future. This is largely due to the fact that some of the "pollutants" for which a water may be listed are actually "effects" of pollutants. Table 7 reflects this collapsed approach. For example, many reaches of the Los Angeles River are listed for ammonia. Some of the same reaches are listed for pH problems while other reaches are listed for algae, scum, and odors. It is very likely the presence of these "pollutants" are interrelated. Excessive nitrogen (reflected here as high levels of ammonia) may lead to a condition of eutrophication (excessive nutrient loading) which can influence pH levels as well as promote increased algal growth. Scum may be evident due to floating algal material and odors may result when excessive algae starts to die off. Thus, it is reasonable to group together these TMDLs (calling it a "nitrogen and related effects" TMDL) and approach the problem by determining the sources of nitrogen loading into the watershed and the appropriate allocations in order to reduce loadings.

Another example relates to the Malibu Creek Watershed. Many of its reaches are listed as impaired due to coliform. Other reaches are listed for swimming restrictions or shellfish harvesting advisories (an effect of elevated coliform levels). It is reasonable to group together these various reaches and "pollutants" together when performing a TMDL. USEPA has produced a number of documents relating to TMDL development; these may be found on the Internet at http://www.epa.gov/owow/tmdl/.

Table 7A lists all of the TMDLs in the Region as well as a schedule for completion. All TMDLs must be completed by 2011 (as requested by U.S. EPA and State Board and per a consent decree). Table 7B lists all TMDLs that we will have started in the next five years (although some will be completed after that time period). It also gives more detail about the scheduling of activities such as actual TMDL development, formation of implementation strategies, and Basin Plan amendments for the next three fiscal years. Table 7C is a resource planning and project management tool detailing resource needs and intermediate milestones for all TMDLs that we will have started in the next three years. More information on TMDLs scheduled for each watershed may be found in the appropriate watershed section.

The following three tables summarize our near-term annual TMDL watershed resource needs (PYs and contract dollars) for the next three fiscal years, beyond what we expect to receive with current funding levels. These needs are also reflected in our resource allocation matrices (for the out-years). **It should be emphasized that we see need for an additional 14.8 PYs during the current fiscal year (FY00/01).**

Near-term Annual (FY00/01) TMDL Watershed Resource Needs (PYs and Contract Dollars)

Watershed	Pollutants	Monitoring/ Assessment	TMDL Develop -ment	Implement-ation Plan Develop-ment	Basin Plan Amendment	TOTAL (PYs)	Contracts ($)
Calleguas Creek	nitrogen, salts, chloride	0.3	1.6	0.2	0.4	2.5	$50,000
Santa Monica Bay	Coliform, nutrients, trash, metals	0.2	3.4	0.2	0.4	4.2	$230,000
LA River	Coliform, nitrogen, trash	0.4	0.7	0.4	0.4	1.9	$100,000
Dominguez Channel/LA -LB Harbors	Coliforms	0.2	0.3	0.2	0.4	1.1	$50,000
Ventura Coastal WMA	Coliform,	0.2	0.3	0.2	—	0.7	—
Los Cerritos WMA	none scheduled for FY00/01	0.2	—	—	—	0.2	—
Santa Clara River	Coliform, nitrogen,	0.2	1.1	0.4	0.4	2.2	$100,000
San Gabriel River	Nitrogen, metals,	0.4	0.9	0.1	—	1.4	$200,000
Ventura River	Eutroph.	0.2	0.9	0.2	—	1.3	$50,000
Channel Islands	no 303(d) waters	0.2	—	—	—	0.2	—
TOTALS		**2.5**	**9.2**	**1.9**	**2.0**	**15.6**	**$780,000**

Additionally, 1 PY each is needed for a region-wide data compiler/interpreter/report-writer and a public outreach person to coordinate workshops and meetings regarding 303(d) list topics.

As has been mentioned many times previously, a major impediment to completing these TMDLs per a 13-year schedule is the less than adequate resources for this program.

Near-term Annual (FY01/02) TMDL Watershed Resource Needs (PYs and Contract Dollars)

Watershed	Pollutants	Monitoring/ Assessment	TMDL Develop -ment	Implement-ation Plan Develop-ment	Basin Plan Amendment	TOTAL (PYs)	Contracts ($)
Calleguas Creek	Salts, pesticides, nutrients	0.8	1.9	0.6	0.4	2.8	$125,000
Santa Monica Bay	Coliform, nutrients, trash, PCBs, Metals	0.6	4.9	0.8	0.6	6.9	$225,000
LA River	Coliform, nitrogen, trash, metals	1.2	0.9	---	---	2.1	$50,000
Dominguez Channel/LA -LB Harbors	coliform	0.4	---	---	0.2	0.6	---
Ventura Coastal WMA	Coliforms	0.4	---	---	0.2	0.6	—
Los Cerritos WMA	NH_3	—	0.5	---	---	0.5	—
Santa Clara River	Eutroph., coliform, nitrogen	0.8	1.2	—	0.4	2.4	$40,000
San Gabriel River	Nitrogen, metals, coliform	1.0	1.2	0.2	0.4	2.8	$50,000
Ventura River	Eutroph.	—	0.3	0.2	—	0.5	$50,000
Channel Islands	no 303(d) waters	—	—	—	—	—	
TOTALS		**5.2**	**10.0**	**108**	**2.2**	**19.2**	**$530,000**

Additionally, 1 PY each is needed for a region-wide data compiler/interpreter/report-writer and a public outreach person to coordinate workshops and meetings regarding 303(d) list topics.

As has been mentioned many times previously, a major impediment to completing these TMDLs per a 13-year schedule is the less than adequate resources for this program.

Near-term Annual (FY02/03) TMDL Watershed Resource Needs (PYs and Contract Dollars)

Watershed	Pollutants	Monitoring/ Assessment	TMDL Develop -ment	Implement-ation Plan Develop-ment	Basin Plan Amendment	TOTAL (PYs)	Contracts ($)
Calleguas Creek	Salts, pesticides, PCBs	0.8	2.4	0.4	0.4	4.0	$125,000
Santa Monica Bay	Coliform, nutrients, PCBs, Metals	1.2	2.8	0.8	0.4	5.2	$225,000
LA River	Metals	---	0.3	0.2	---	0.5	$50,000
Dominguez Channel/LA -LB Harbors	none scheduled for FY02/03 (startup work)	---	---	---	---	---	---
Ventura Coastal WMA	PAHs, zinc	---	1.7	0.2	---	1.9	$60,000
Los Cerritos WMA	Pesticides, metals, PAHs, NH_3	0.2	3.4	0.2	---	3.8	$125,000
Santa Clara River	Chloride, eutroph., trash	0.4	1.2	0.2	---	1.8	$50,000
San Gabriel River	Nitrogen, Coliform	0.4	0.7	0.4	0.2	1.7	$40,000
Ventura River	Eutroph.	0.4	---	---	0.2	0.6	---
Channel Islands	no 303(d) waters	---	---	---	---	---	
TOTALS		**3.4**	**12.5**	**2.4**	**1.2**	**19.5**	**$675,000**

Additionally, 1 PY each is needed for a region-wide data compiler/interpreter/report-writer and a public outreach person to coordinate workshops and meetings regarding 303(d) list topics.

As has been mentioned many times previously, a major impediment to completing these TMDLs per a 13-year schedule is the less than adequate resources for this program.

With an anticipated near-term augmentation need of 14-19 PYs/year, we are actively seeking funds for this effort.

If we were required to redirect other resources (assuming we had the flexibility, which for the most part we don't), it would have a disastrous impact on our other programs. This magnitude of redirection would require almost a 50% reduction in our NPDES program which is already severely underfunded based on the number of facilities we regulate. Alternatively, we could cease all enforcement efforts and about one-third of our surface water regulatory program. None of these are acceptable alternatives.

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Section 4 . *Appendices*

Appendix 4.1 NPDES Wastewater Permit Reissuance (2000 – 2005)

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2001/2002

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
SANTA CLARA RIVER WATERSHED										
majors										
City of Santa Paula/OMI	Santa Paula WWRP, NPDES	SANTA PAULA	CA0054224	4A560108001	1759	1	3/10/02	1st Q	97-041	DDOMIND
Los Angeles County San Dist	Valencia WWRP, NPDES	VALENCIA	CA0054216	4A190107023	4993	1	5/10/00	2nd Q	95-081	DDOMIND
Los Angeles County San Dist	Saugus WWRP, NPDES	SAUGUS	CA0054313	4A190107021	2960	1	5/10/00	2nd Q	95-080	DDOMIND
San Buenaventura City Of	Ventura WWRP, NPDES	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	CA0053651	4A560107001	1822	1	5/10/00	1st Q	95-074	DDOMIND
minors										
Castaic Lake Water Agency	Earl Schmidt Filtration Plant	CASTAIC	CA0059030	4A190116001	6544	3	3/10/02	2nd Q	97-030	DMISCEL
Dept. Of Water Resources	William E. Warne Power Plant	PYRAMID LAKE	CA0059188	4A190805002	6610	3	4/10/04	2nd Q	99-015	DPROCES
H. R. Textron Inc.	Valencia Facility	VALENCIA	CA0003271	4A192332001	6024	3	9/10/01	3rd Q	96-066	DMISCEL
H. R. Textron Inc.	Valencia Facility	VALENCIA	CA0064017	4A192332003	7727	3	9/10/01	3rd Q	96-078	HCNWTRS
Harris Water Conditioning	Culligan Water	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	CA0060267	4A561037001	6818	3	11/10/01	3rd Q	96-095	DMISCEL
Keysor-Century Corp	Pvc-Pva Copolymer Mfg, Saugus	SAUGUS	CA0057126	4A192000001	1954	2	5/10/03	2nd Q	98-032	DSTORMS
Los Angeles City of DWP	Castaic Power Plant	CASTAIC	CA0055824	4A193500005	6112	2	2/10/03	2nd Q	98-020	DPROCES
Los Angeles City of DWP	Tunnel Nos. 1&4	SANTA CLARITA	CA0058432	4B190106061	6313	3	1/10/03	2nd Q	98-006	DCNWTRS
Los Angeles County Parks & Rec	Val Verde Co. Park Swim Pool	SAUGUS	CA0062561	4A190107086	7140	3	3/10/02	2nd Q	97-062	DMISCEL
Metropolitan Water Dist. Of SC	Foothill Feeder Power Plant	CASTAIC	CA0059641	4A190115006	6743	3	9/10/03	2nd Q	98-066	DNONCON
National Technical Systems	Rye Canyon Road Facility	VALENCIA	CA0064122	4A191152001	7793	3	4/10/02	2nd Q	97-048	DNONCON
Rayne Water Systems Of Ventura	Soft Water Sales & Svc,Ventura	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	CA0002658	4A569002001	3070	3	10/10/01	3rd Q	96-082	DFILBRI
Santa Clarita, City Of	Outdoor Project Homes	SANTA CLARITA	CA0061638	4A191142001	6945	3	9/10/01	3rd Q	96-079	DMISCEL
Six Flags Magic Mountain	Amusement Park, Valencia	VALENCIA	CA0003352	4A199002002	6045	2	1/10/03	3rd Q	98-005	DMISCEL
Texaco Group Inc.	Pacific Coast Pipeline Site	FILLMORE	CA0063240	4A561057001	7346	3	9/10/00	3rd Q	95-146	DCNWTRS
Ventura Regional San District	Fillmore WWTP, NPDES	FILLMORE	CA0059021	4A560101002	6523	2	4/10/97	1st Q	92-023	DDOMIND
general permits										
Castaic Lake Water Agency	Lateral Extension Pipeline	LOS ANGELES (COUNTY)	CAG994001	4A196000397	7882	3	4/10/02	4th Q	97-045	DMISCEL
Chevron U.S.A. Inc.	Former Service Station 9-2521	OXNARD	CAG834001	4A566600124	8012	2	4/10/02	4th Q	97-046	HCNWTRS
Enloe Well Drilling	Peter J. Pitchess Honor Ranch	SAUGUS	CAG994001	4A196000492	8040	3	4/10/02	4th Q	97-045	IMISCEL
HMH Construction Co. Inc.	Northfield Business Park proj.	OXNARD	CAG994001	4A566000441	7947	3	4/10/02	4th Q	97-045	DMISCEL

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Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2001/2002 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Los Angeles County San Dist	Dist. 32 Main Trunk Sewer	VALENCIA	CAG994001	4A196000424	7906	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles County San Dist	Valencia Water Reclamation	VALENCIA	CAG994001	4A196000102	7296	3	4/10/02	4th Q	97-045	DMISCEL
McDonald's Restaurant	GW-Mcdonald's Restaurant	GORMAN	CAG994001	4A196000160	7464	3	4/10/02	4th Q	97-045	DMISCEL
Mobil Oil Corp.	Newhall Station	SANTA CLARITA	CAG834001	4A196600132	8178	2	4/10/02	4th Q	97-046	DWSHWTR
Mobil Oil Corp.	Service Station # 18-KCM	SANTA CLARITA	CAG834001	4B196600125	8035	2	4/10/02	4th Q	97-046	DCNWTRS
Ogden Constructors	Santa Paula Improvement,Reach2	SANTA PAULA	CAG994001	4A566000472	8002	3	4/10/02	4th Q	97-045	IMISCEL
Robinson Development Services	Sand Canyon Bridge Widening	SANTA CLARITA	CAG994001	4A196000506	8078	3	4/10/02	4th Q	97-045	IMISCEL
San Buenaventura City Of	Ventura WWRP	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	CAG994001	4A566000381	7848	3	4/10/02	4th Q	97-045	DMISCEL
Santa Clarita Community Colleg	College Of The Canyons	SANTA CLARITA	CAG994003	4A196400040	7324	3	5/10/03	4th Q	98-055	DMISCEL
Santa Clarita, City Of	GW - Four Oak Wells	SANTA CLARITA	CAG994001	4A196000323	7812	3	4/10/02	4th Q	97-045	DMISCEL
Santa Clarita, City Of	Golden Valley Road Extension	SANTA CLARITA	CAG994001	4A196000510	8090	3	4/10/02	4th Q	97-045	IMISCEL
Southern California Gas Co.	Lines 235/335	SANTA CLARITA	CAG674001	4A196300108	8091	3	4/10/02	4th Q	97-047	IMISCEL
Valencia Co.	Avenue Scott Bridge	SANTA CLARITA	CAG994001	4A196000473	8004	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Co.	Decoro Drive Bridge	SANTA CLARITA	CAG994001	4A196000534	8153	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Co.	Del Lago Dewatering Proj.	SANTA CLARITA	CAG994001	4A196000455	7968	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Co.	East Creek Channel Lining Proj	SANTA CLARITA	CAG994001	4A196000539	8165	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Co.	South River Dewatering Proj.	SANTA CLARITA	CAG994001	4A196000467	7990	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Water Company	Water Well No. 205	SANTA CLARITA	CAG994001	4B196000466	7989	3	4/10/02	4th Q	97-045	IMISCEL
Valencia Water Company	Wells 10, S6, S7, and S8	SANTA CLARITA	CAG994001	4A196000499	8054	3	4/10/02	4th Q	97-045	IMISCEL
CALLEGUAS CREEK WATERSHED										
majors										
Camarillo Sanitary District	Camarillo WWRP, NPDES	CAMARILLO	CA0053597	4A560100001	1278	1	5/10/01	2nd Q	97-125	DDOMIND
Simi Valley, City Of	Simi Valley WWRP, NPDES	SIMI VALLEY	CA0055221	4A560110001	3021	1	5/10/01	2nd Q	97-122	DDOMIND
Thousand Oaks City Of DPW	Hill Canyon WWRP, NPDES	CAMARILLO	CA0056294	4A560112001	4917	1	5/10/01	2nd Q	97-123	DDOMIND
minors										
Camrosa Water District	Camrosa WWRP, NPDES	CAMARILLO	CA0059501	4A560106003	6769	3	12/10/03	2nd Q	00-009	DDOMEST
Emery Worldwide	Pti Technologics	NEWBURY PARK	CA0064050	4A562443001	7743	2	11/10/01	2nd Q	96-090	HCNWTRS
Exxon Co., U.S.A.	22 Sites Groundwater Assessmen	LOS ANGELES	CA0063304	4B191015005	7394	1	4/10/05	3rd Q	00-042	DMISCEL
Northrop Grumman Corp. Masd	Newbury Park - NPDES	NEWBURY PARK	CA0062588	4A562436001	7093	2	8/31/05	3rd Q	00-126	HCNWTRS

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2001/2002 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Rockwell Science Center LLC	Tank Leak-Hillcrest Facility	NEWBURY PARK	CA0060348	4A562074001	6808	3	5/10/01	2nd Q	96-048	HCNWTRS
Teleflex Control Systems	The Talley Site, Newbury Park	NEWBURY PARK	CA0059609	4A562397002	6729	2	2/10/02	2nd Q	97-032	HCNWTRS
Thousand Oaks City Of DPW	Olsen Road WWRP, NPDES	THOUSAND OAKS	CA0056359	4A560112002	4761	2	5/10/01	2nd Q	97-124	DDOMIND
Tosco Corp.	Tosco Gasoline Service Station		CA0064343	4B192131032	8089	3	11/9/04	3rd Q	99-130	DCNWTRS
Transit Mixed Concrete Co	Sand&Gravel,Ponds-Overflow	MOORPARK	CA0059315	4A562022001	6658	3	5/10/01	2nd Q	96-046	DMISCEL
Ventura Co Water Works Dist.	Moorpark WWTP	MOORPARK	CA0063274	4A560103003	7513	2	12/10/03	2nd Q	00-049	DDOMIND
general permits										
Calleguas Municipal Water Dist	Calleguas Conduit North Branch	SIMI VALLEY	CAG994001	4A566000508	8087	3	4/10/02	4th Q	97-045	DMISCEL
Calleguas Municipal Water Dist	Fairview Pump Station	MOORPARK	CAG994001	4A566000049	7149	3	4/10/02	4th Q	97-045	DMISCEL
Calleguas Municipal Water Dist	Grimes Canyon Road Wellfiel	MOORPARK	CAG994001	4A566000190	7556	3	4/10/02	4th Q	97-045	DMISCEL
Calleguas Municipal Water Dist	Grimes Canyon Wellfield #2	MOORPARK	CAG994001	4A566000317	7817	3	4/10/02	4th Q	97-045	DMISCEL
Calleguas Municipal Water Dist	Well Nos. ASR-17 and ASR-18	MOORPARK	CAG994001	4A566000464	7985	3	4/10/02	4th Q	97-045	IMISCEL
Former Wendy ARCO	Former Wendy ARCO Service St	NEWBURY PARK	CAG834001	4A566600117	7876	2	4/10/02	4th Q	97-046	HCNWTRS
Mobil Oil Corp.	Tank Leak-Mobil Ss#11-H7a	NEWBURY PARK	CAG834001	4A566600116	7192	2	4/10/02	4th Q	97-046	HCNWTRS
Oxnard Community College	Tank Leak-Oxnard Community Col	OXNARD	CAG834001	4A566600099	7771	2	4/10/02	4th Q	97-046	HCNWTRS
Thousand Oaks City of	Unit W & F Interceptor - II	THOUSAND OAKS	CAG994001	4A566000477	8009	3	4/10/02	4th Q	97-045	IMISCEL
Unocal Corp.	Former Unocal Station #4687	THOUSAND OAKS	CAG834001	4A566000129	8150	2	4/10/02	4th Q	97-046	DCNWTRS
US Navy Naval Air Weapons Stat	Tank Leak-Navy Exchange Gas St	POINT MUGU	CAG834001	4A566600084	6961	2	4/10/02	4th Q	97-046	HCNWTRS
Ventura Co Water Works Dist.	Moorpark WWTP	MOORPARK	CAG674001	4A566300107	8086	3	4/10/02	4th Q	97-047	IMISCEL

***General permit dischargers will be reviewed and may not be "renewed" but allowed to continue with enrollment**

Santa Clara River Watershed

CAG834001 3
CAG994001 18
CAG994003 1
CAG674001 1

DDOMIND 5
DMISCEL 14
DPROCESS 2
HCNWTRS 2
DSTORMS 1
DNONCON 2
DFILBRI 1
DCNWTRS 3
IMISCEL 12
DWSHWTR 1

Calleguas Creek Watershed

CAG834001 5
CAG994001 6
CAG674001 1

DDOMIND 5
DDOMEST 1
HCNWTRS 8
DMISCEL 6
DCNWTRS 2
IMISCEL 3

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2002/2003

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
DOMINGUEZ CHANNEL-LA/LB HARBOR WMA										
majors										
Arco Petroleum Products Co.	Watson Refinery	CARSON	CA0000680	4B192010008	5424	2	8/10/98	1st Q	93-051	DCNWTRS
Equilon Enterprises LLC	Carson Plant	CARSON	CA0000809	4B192108004	6108	2	11/10/98	1st Q	93-073	DSTORMS
Equilon Enterprises LLC	L.A. Refining Co. (Wilmington)	WILMINGTON	CA0003778	4B192121001	5427	1	9/16/04	1st Q	99-093	HCONTAC
LA City Bureau of Sanitation	Terminal Island WWTP	SAN PEDRO	CA0053856	4B190106005	2171	1	2/10/98	2nd Q	93-014	DDOMEST
Long Beach Generation LLC	Long Beach Generation Station	LONG BEACH	CA0001171	4B192111002	5764	1	11/10/99	2nd Q	94-130	DNONCON
Los Angeles City of DWP	Harbor Generating Station	WILMINGTON	CA0000361	4B193500004	2020	1	1/10/00	2ndQ	95-027	DNONCON
Mobil Oil Corp.	Torrance Refinery, NPDES	TORRANCE	CA0055387	4B192079002	5742	1	1/10/98	1st Q	93-003	HSTORMS
Tosco Corp.	L.A.Refinery, Wilmington Plant	WILMINGTON	CA0000035	4B192131002	6103	1	3/10/98	1st Q	93-019	HSTORMS
Tosco Corp.	L.A.Refinery, Carson Plant	CARSON	CA0063185	4B192131026	7352	2	12/10/98	1st Q	94-001	DSTORMS
Tutor-Saliba Team	Alameda Mid-Corridor Trench Pj	LYNWOOD	CA0064351	4B191340001	8084	1	12/31/01	1st Q	99-143	DMISCEL
minors										
AIR PRODUCTS AND CHEMICALS,INC	Hydrogen Plant & Related Fac.	WILMINGTON	CA0063363	4B191285001	7466	2	10/10/99	3rd Q	94-116	DSTORMS
Al Larson Boat Shop	Al Larson Boat Shop	TERMINAL ISLAND	CA0061051	4B192538001	6920	3	5/10/02	3rd Q	97-079	DSTORMS
Arco C.Q.C. Kiln, Inc.	Arco C.Q.C. Kiln, Inc.	WILMINGTON	CA0059153	4B192208003	6571	2	12/10/00	3rd Q	96-004	DSTORMS
Arco Pipe Line Co.	Carson Crude Oil Terminal	CARSON	CA0060232	4B192010019	6810	3	5/10/02	2nd Q	97-075	DSTORMS
Arco Products Co.	Marine Terminal,1,Berth 121,LB	LONG BEACH	CA0059285	4B192010015	6643	3	6/10/05	2nd Q	00-089	DSTORMS
Arco Terminal Services Corp.	Long Beach Marine Terminal 2	LONG BEACH	CA0000442	4B192010018	6802	2	12/10/01	2nd Q	97-006	DSTORMS
Arco Terminal Services Corp.	Long Beach Marine Terminal 3	LONG BEACH	CA0000451	4B192010003	6023	3	9/10/00	2nd Q	95-141	DSTORMS
California Sulphur Co.	Sulfur Pelletizing, Wilmington	WILMINGTON	CA0059064	4B192143001	6546	2	2/10/02	2nd Q	97-021	DSTORMS
Churchill Downs California Co.	Hollywood Park	INGLEWOOD	CA0064211	4B191303001	8100	3	9/10/04	2nd Q	99-105	DMISCEL
Dow Chemical Co.	Long Beach Marine Terminal	LONG BEACH	CA0064165	4B192614001	7873	2	2/10/03	2nd Q	98-019	DWSHWTR
Edoco	Edoco	CARSON	CA0002941	4B192034001	4420	3	1/10/99	3rd Q	94-012	DSTORMS
Elixir Industries	Tank Leak-Elixir Industries	GARDENA	CA0062537	4B192575001	7104	3	12/10/01	4th Q	97-005	HCNWTRS
Equilon Enterprises LLC	Carson Sulfur Recovery Plant	CARSON	CA0002020	4B192121002	1511	2	6/10/05	2nd Q	00-113	DSTORMS
Equilon Enterprises LLC	Mormon Island Marine Terminal	WILMINGTON	CA0003557	4B192108009	1596	3	5/10/05	2nd Q	00-086	DSTORMS
Exxon Co., U.S.A.	22 Sites Groundwater Assessmen	LOS ANGELES	CA0063304	4B191015005	7394	1	4/10/05	4th Q	00-042	DMISCEL
Fairchild Holding Corp.	Tank Leak-Voi-Shan Redondo Bch	REDONDO BEACH	CA0060631	4B192525001	6841	3	2/10/02	4th Q	97-020	HCNWTRS
Gardena, City Of,	Primm Memorial Swimming Pool	GARDENA	CA0056413	4B190118001	4152	3	7/10/00	1st Q	95-097	DFILBRI
GATX Tank Storage Terminals Co	San Pedro Marine Terminal	SAN PEDRO	CA0001911	4B192124001	4192	2	2/10/01	2nd Q	96-010	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2002/2003 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
GATX Tank Storage Terminals Co	Los Angeles Harbor Terminal	SAN PEDRO	CA0055816	4B192238001	5935	2	3/10/00	4th Q	95-036	DSTORMS
GATX Tank Storage Terminals Co	Carson Terminal	CARSON	CA0056863	4B192238002	5244	2	5/10/05	4th Q	00-087	DSTORMS
GATX Tank Storage Terminals Co	Berth 172, L.A.Marine Terminal	WILMINGTON	CA0060178	4B192407002	6822	2	7/10/00	4th Q	95-091	DSTORMS
Harbor Cogeneration Company	Harbor Cogeneration Company	WILMINGTON	CA0060003	4B192520001	6797	2	4/10/02	3rd Q	97-053	DFILBRI
Hitco Carbon Composites, Inc	Hitco/Defence Prod Div,	GARDENA	CA0059048	4B192128001	6520	3	5/10/98	3rd Q	93-028	DNONCON
Honeywell Inc.	Torrance Facility	TORRANCE	CA0058688	4B192354002	6417	3	2/10/99	3rd Q	94-014	DNONCON
Honeywell Inc.	Tank Leak-Honeywell Inc.	GARDENA	CA0062162	4B191263001	7015	3	2/10/02	4th Q	97-022	HCNWTRS
Long Beach City Of	Southeast Resource Recovery	LONG BEACH	CA0059544	4B190105017	6707	3	7/10/98	3rd Q	97-084	DSTORMS
Los Angeles City of DWP	Harbor Steam Plant,N Skim Tank	WILMINGTON	CA0056383	4B190106039	6004	3	11/10/97	4th Q	92-085	DSTORMS
Los Angeles City of DWP	Harbor Steam Plant,Skim Pond	WILMINGTON	CA0056448	4B190106040	6005	3	5/10/02	4th Q	97-080	DSTORMS
Los Angeles City of DWP	Harbor G.S. - Marine Tank Farm	WILMINGTON	CA0057037	4B190106046	6155	3	12/10/01	2nd Q	97-003	DSTORMS
Los Angeles City of DWP	Olympic Tank Farm Skim Pond	WILMINGTON	CA0057568	4B190106051	6211	3	6/10/00	4th Q	95-066	DSTORMS
Los Angeles County Parks & Rec	Lennox County Park	LOS ANGELES	CA0062766	4B191289001	7532	3	4/10/01	1st Q	96-029	DMISCEL
Metropolitan Stevedore Co.	Metropolitan Stevedore Co.	LONG BEACH	CA0057746	4B192078001	5354	2	5/10/02	3rd Q	97-078	DSTORMS
Mobil Oil Corp.	Southwestern Terminal-Area I	TERMINAL ISLAND	CA0003689	4B192079001	1558	3	3/10/02	1st Q	97-060	DPROCES
Morton International, Inc.	Tank Leak-Bee Chemical Co.	GARDENA	CA0060992	4B192539001	6922	3	2/10/02	4th Q	97-023	HCNWTRS
Morton International, Inc.	Morton Salt - Long Beach	LONG BEACH	CA0061476	4B192543001	6949	3	5/10/02	1st Q	97-081	DSTORMS
Northrop Grumman Corp. Masd	El Segundo Facility	EL SEGUNDO	CA0059226	4B192081002	6609	3	11/10/99	1st Q	94-119	DNONCON
Paktank Corp. - Los Angeles	Petroleum & Chemical Terminal	WILMINGTON	CA0055247	4B199019001	5985	2	4/10/99	2nd Q	94-036	DSTORMS
Paktank Corp. - Los Angeles	Wilmington Liq. Bulk Terminals	WILMINGTON	CA0063177	4B199019002	7298	2	3/10/00	2nd Q	95-041	HSTORMS
Permalite Repro Media Corp.	Permalite Repro Media Corp.	CARSON	CA0059871	4B192512001	6759	2	8/10/01	1st Q	96-067	DSTORMS
Petro Diamond Terminal Company	Marine Terminal, Berth 83, Lb	LONG BEACH	CA0059358	4B192197001	6677	3	12/10/99	2nd Q	95-009	DSTORMS
Plaskolite West, Inc.	Continental Acrylics, Inc.	COMPTON	CA0060798	4B192533001	6895	3	1/10/00	3rd Q	95-026	DCONTAC
Port of Los Angeles	Anaheim St. Viaduct Project	LOS ANGELES	CA0063851	4B190106095	7591	2	8/10/00	1st Q	95-121	DCNWTRS
Port of Los Angeles	New Dock Street Pump Statio	TERMINAL ISLAND	CA0064157	4B191310001	7856	3	11/10/02	1st Q	97-138	DMISCEL
Praxair, Inc.	Praxair, Wilmington	WILMINGTON	CA0001848	4B192140001	5428	2	11/10/00	2nd Q	95-156	DCONTAC
Redman Equipment & Mfg Co	Torrance Heat Exchanger Mfg&Rp	TORRANCE	CA0058726	4B192090001	6465	3	4/10/05	3rd Q	00-065	DSTORMS
Rhodia Inc.	Dominguez Ind Chem Plant	CARSON	CA0058629	4B192007002	6379	2	8/10/99	3rd Q	94-092	DSTORMS
San Pedro Boatworks	San Pedro Boatworks-Berth 44	SAN PEDRO	CA0061042	4B192536001	6918	3	4/10/02	3rd Q	97-059	DSTORMS
Shore Terminal LLC	Wilmington Marine Terminal	WILMINGTON	CA0055263	4B192263001	5915	2	5/10/00	2nd Q	95-072	DSTORMS
Southern Ca. Marine Institute	Southern Ca. Marine Institute	TERMINAL ISLAND	CA0058556	4B191035001	6362	3	12/10/99	1st Q	95-010	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2002/2003 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Southwest Marine, Inc.	Southwest Marine, Inc.	TERMINAL ISLAND	CA0000868	4B192017002	2061	3	10/10/00	3rd Q	95-143	DNONCON
The Jankovich Co.	The Jankovich Co.-Berth 74	SAN PEDRO	CA0002798	4B192108007	6078	2	1/10/01	3rd Q	96-011	DSTORMS
Tidelands Oil Production Co.	Wilmington And Terminal Island	WILMINGTON	CA0001813	4B192023001	6080	2	7/10/99	1st Q	94-063	DSTORMS
Tosco Corp.	Los Angeles Terminal West	LOS ANGELES	CA0059846	4B192131013	6773	2	5/10/02	1st Q	97-082	DSTORMS
Tri-Union Seafoods, LLC	Plant Nos. 1 & 2	SAN PEDRO	CA0000469	4B192089001	5796	1	5/10/02	4th Q	97-077	DNONCON
TRW Inc.	Hawthorne Site	HAWTHORNE	CA0063916	4B192557002	7698	2	6/10/01	4th Q	96-060	HCNWTRS
TRW Inc.	Space Park Facility	REDONDO BEACH	CA0063924	4B192557003	7697	2	6/10/01	4th Q	96-059	HCNWTRS
Ultramar Inc.	Marine Term, Berth 164	WILMINGTON	CA0055719	4B192023002	2165	3	7/10/99	2nd Q	94-064	DSTORMS
United States Borax & Chem Cor	Wilmington Plant	WILMINGTON	CA0000787	4B192129002	1449	2	12/10/01	3rd Q	97-004	HNONCON
US Navy Defense Logistics Agen	Defense Fuel Supply Pier 12 Lb	LONG BEACH	CA0060496	4B190705002	6877	3	11/10/99	3rd Q	94-125	DSTORMS
Western Fuel Oil Co.	Western Fuel Oil Co.	SAN PEDRO	CA0001902	4B192137001	0907	2	7/10/01	2nd Q	96-064	DSTORMS
Westside Concrete Co.	Greene's Ready-Mixed Concrete	TORRANCE	CA0002992	4B192047001	6007	3	5/10/00	4th Q	95-070	DSTORMS
Westway Terminal Company	Westway Terminal-Berths 70-71	SAN PEDRO	CA0002186	4B192407001	5960	2	7/10/00	3rd Q	97-139	DSTORMS
general permits										
AboveNet Communications, Inc.	Silverado Aquifer Testing	EL SEGUNDO	CAG994001	4B196000551	8188	3	4/10/02	2nd Q	97-045	IMISCEL
AIR PRODUCTS AND CHEMICALS,INC	Carson Hydrogen Plant	CARSON	CAG994003	4B196400054	8061	3	5/10/03	4th Q	98-055	DNONCON
Arco Petroleum Products Co.	Tank Leak-4000 W. Redondo Beac	TORRANCE	CAG834001	4B196600007	7253	2	4/10/02	4th Q	97-046	HCNWTRS
California Water Service Co.	Ht-Hill Tank	TORRANCE	CAG674001	4B196300054	7680	3	4/10/02	3rd Q	97-047	DMISCEL
California Water Service Co.	Ht-Reservoir #1	TORRANCE	CAG674001	4B196300053	7678	3	4/10/02	3rd Q	97-047	DMISCEL
California Water Service Co.	Gw-Well #32 & #33	TORRANCE	CAG994001	4B196000310	7781	3	4/10/02	2nd Q	97-045	DMISCEL
California Water Service Co.	Well # 98	LONG BEACH	CAG994001	4B196000521	8133	3	4/10/02	2nd Q	97-045	IMISCEL
California Water Service Co.	Wells 19A, 75A, 77 & 79	CARSON	CAG994001	4B196000380	7846	3	4/10/02	2nd Q	97-045	DMISCEL
Caltrans	Dominguez Channel Watershed	GARDENA	CAG994001	4B196000287	7732	3	4/10/02	2nd Q	97-045	DMISCEL
Defense Fuel Support Point	DFSP San Pedro-Pump House Area	SAN PEDRO	CAG834001	4B196600122	7565	2	4/10/02	4th Q	97-046	DCNWTRS
Department of Navy	Former LB Naval Sta, NEX Gas S	LONG BEACH	CAG834001	4B196600123	7566	2	4/10/02	4th Q	97-046	HCNWTRS
El Segundo, City of	Palot Test Well Facility	EL SEGUNDO	CAG994002	4B196100021	7911	3	4/10/02	4th Q	97-043	DMISCEL
Equilon Enterprises LLC	Tank Leak-2186 Redondo Bch Bl.	TORRANCE	CAG834001	4B196600030	7366	2	4/10/02	4th Q	97-046	HCNWTRS
GATX Tank Storage Terminals Co	Carson Terminal	CARSON	CAG674001	4B196300118	8156	3	4/10/02	3rd Q	97-047	DMISCEL
GATX Tank Storage Terminals Co	Ht-Gatx, Carson	CARSON	CAG674001	4B196300004	7107	3	4/10/02	3rd Q	97-047	DMISCEL
GATX Tank Storage Terminals Co	Gaffey Street Terminal	SAN PEDRO	CAG674001	4B196300119	8157	3	4/10/02	3rd Q	97-047	DMISCEL
GATX Tank Storage Terminals Co	Ht-Berth 118-119	SAN PEDRO	CAG674001	4B196300023	7332	3	4/10/02	3rd Q	97-047	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2002/2003 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
GATX Tank Storage Terminals Co	Ht-Berth 172	WILMINGTON	CAG674001	4B196300020	7291	3	4/10/02	3rd Q	97-047	DMISCEL
GATX Tank Storage Terminals Co	Westway Terminal, Berth 79	SAN PEDRO	CAG914001	4B196800027	8077	2	4/10/02	4th Q	97-044	DMISCEL
Heinz Pet Products Div.	Heinz Pet Products	TERMINAL ISLAND	CAG994003	4B196400065	5795	3	5/10/03	4th Q	98-055	DNONCON
LA Co Dept of Public Works	Dominguez Gap Barrier 1,2, &3	WILMINGTON	CAG994001	4B196000497	6089	3	4/10/02	2nd Q	97-045	DMISCEL
LA Co Dept of Public Works	Dominguez Gap Barrier 1,2, &3	WILMINGTON	CAG994001	4B196000497	6089	3	4/10/02	2nd Q	97-045	DMISCEL
LA Co Dept of Public Works	Griffith St. Storm Drain Proj	CARSON	CAG994002	4B196100057	8177	3	4/10/02	4th Q	97-043	NCNWTRS
Los Angeles City of DWP	Marine Tank Farm	WILMINGTON	CAG674001	4B196300040	7495	3	4/10/02	3rd Q	97-047	DMISCEL
Los Angeles City of DWP	Pipeline Terminal Island	SAN PEDRO	CAG674001	4B196300103	8045	3	4/10/02	3rd Q	97-047	IMISCEL
Los Angeles City of DWP	Los Angeles Harbor WRP	SAN PEDRO	CAG994002	4B196100023	7929	3	4/10/02	4th Q	97-043	DMISCEL
Mobil Oil Corp	Southeast Terminal II	TERMINAL ISLAND	CAG674001	4B196300098	8000	3	4/10/02	3rd Q	97-047	DMISCEL
Mobil Oil Corp.	Southwestern Terminal-Area I	TERMINAL ISLAND	CAG674001	4B196300090	7952	3	4/10/02	3rd Q	97-047	DMISCEL
Port Of Long Beach	Port Access Demonstration	LONG BEACH	CAG994001	4B196000179	7510	3	4/10/02	2nd Q	97-045	DMISCEL
Port Of Long Beach	Henry Ford Sewer Pump Station	LONG BEACH	CAG994002	4B196100016	7889	3	4/10/02	4th Q	97-043	DMISCEL
Port of Los Angeles	West Basin ICTF Project	SAN PEDRO	CAG994002	4B196100038	8117	3	4/10/02	4th Q	97-043	DMISCEL
SFPP, LP	Watson Station	CARSON	CAG674001	4B196300121	8170	3	4/10/02	3rd Q	97-047	IMISCEL
Southern California Edison	EPTC Pipeline (Dominguez Ch)		CAG674001	4B196300109	8094	3	4/10/02	3rd Q	97-047	IMISCEL
Southern California Edison	EPTC Pipeline (LA/LB Harbors)		CAG674001	4B196300110	8095	3	4/10/02	3rd Q	97-047	IMISCEL
Southern California Edison	EPTC Pipeline (Dominguez Ch)		CAG994002	4B196100039	8124	3	4/10/02	4th Q	97-043	DMISCEL
Southern California Edison	EPTC Pipeline (LA/LB Harbors)		CAG994002	4B196100041	8126	3	4/10/02	4th Q	97-043	DMISCEL
Southern California Water Co.	Dalton Well	GARDENA	CAG994001	4B196000486	8014	3	4/10/02	2nd Q	97-045	NMISCEL
Southern California Water Co.	Ocean Gate Well	HAWTHORNE	CAG994001	4B196000447	7959	3	4/10/02	2nd Q	97-045	DMISCEL
Southern California Water Co.	Southwest District	CARSON	CAG994001	4B196000394	7878	3	4/10/02	2nd Q	97-045	DMISCEL
Southern California Water Co.	Yukon Wells 1 & 2	INGLEWOOD	CAG994001	4B196000485	8026	3	4/10/02	2nd Q	97-045	NMISCEL
Southern California Water Co.	Chicago & Compton Doty Wells	LAWNDALE	CAG994002	4B196100026	7958	3	4/10/02	4th Q	97-043	DMISCEL
Southern California Water Co.	Goldmedal Plant	HAWTHORNE	CAG994003	4B196400037	7916	3	5/10/03	4th Q	98-055	DMISCEL
Southern California Water Co	Truro Fe & Mn Filtration Plant	INGLEWOOD	CAG994003	4B196400045	8027	3	5/10/03	4th Q	98-055	NFILBRI
Syart Parking Structures, Inc.	Tank Leak-SYART PARKING STRUCT	GARDENA	CAG834001	4B196600036	7374	2	4/10/02	4th Q	97-046	HCNWTRS
Tesoro Petroleum	Target Store-290	GARDENA	CAG914001	4B196800023	8038	2	4/10/02	4th Q	97-044	IMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2002/2003 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Tosco Corp.	HI-L. A. Refinery, Wilmington	WILMINGTON	CAG674001	4B196300024	7337	3	4/10/02	3rd Q	97-047	DMISCEL
Water Repenishment Dist Of S.C	West Basin Observation Well	TORRANCE	CAG994001	4B196000162	7470	3	4/10/02	2nd Q	97-045	DMISCEL
Wyndham Hotels & Resorts	Wyndham Hotel at L.A. Airport	LOS ANGELES	CAG994003	4B196400060	4581	3	5/10/03	4th Q	98-055	IMISCEL

***General permit dischargers will be reviewed and may not be "renewed" but allowed to continue with enrollment**

CAG674001 16
CAG834001 5
CAG914001 2
CAG994001 13
CAG994002 9
CAG994003 5

NMISCEL 2
NCNWTRS 1
DCNWTRS 3
DSTORMS 38
HCONTACT 1
HSTORMS 3
DMISCEL 37
DWSHWTR 1
HCNWTRS 10
DFILBRI 2
DNONCON 9
DPROCESS 1
IMISCEL 9
NFILBRI 1
DCONTAC 2
DDOMEST 1
HNONCON 1

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Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
SANTA MONICA BAY WMA										
majors										
AES Redondo Beach, LLC	Redondo Generating Station	REDONDO BEACH	CA0001201	4B192111003	0536	1	5/10/05	1st Q	00-085	DPROCES
Chevron U.S.A. Inc.	El Segundo Refinery	EL SEGUNDO	CA0000337	4B192113001	1603	1	8/10/02	1st Q	97-112	HSTORMS
El Segundo Power, L.L.C.	El Segundo Generating Station	EL SEGUNDO	CA0001147	4B192111001	4667	1	5/10/05	1st Q	00-084	DPROCES
Equilon Enterprises LLC	Shell Station #204-1944-0100	CULVER CITY	CA0064289	4B191312001	8030	1	6/10/04	3rd Q	99-065	DCNWTRS
LA City Bureau of Sanitation	Hyperion WWTP, NPDES	PLAYA DEL REY	CA0109991	4B190106002	1492	1	2/10/99	2nd Q	94-021	DDOMIND
Las Virgenes MWD	Tapia WWRP, NPDES	CALABASAS	CA0056014	4B190104001	4760	1	10/10/02	2nd Q	97-135	DDOMIND
Los Angeles City of DWP	Scattergood Generating Station	PLAYA DEL REY	CA0000370	4B193500003	1886	1	5/10/05	1st Q	00-083	DCONTAC
Los Angeles County San Dist	JWPCP, Carson NPDES	CARSON	CA0053813	4B190107013	1758	1	5/10/02	2nd Q	97-090	DDOMIND
Mobil Oil Corp.	Service Station #18-FX-5	CULVER CITY	CA0064301	4B192079027	8055	1	6/10/04	3rd Q	99-062	DCNWTRS
minors										
4201 Wilshire, LLC	HARBOR ASSOCIATES	LOS ANGELES	CA0054861	4B191083001	5225	3	6/10/02	2nd Q	97-097	DMISCEL
Adams Plaza	Adams Plaza	LOS ANGELES	CA0058297	4B191101001	6302	3	6/10/02	2nd Q	97-101	DNONCON
Beverly Springs Medical Center	Beverly Hot Springs	LOS ANGELES	CA0062189	4B191266001	7023	3	6/10/02	2nd Q	97-098	DMISCEL
Cushman & Wakefield Of Calif.	American City Bank Building	LOS ANGELES	CA0055361	4B191121001	2556	3	7/10/02	2nd Q	97-103	DNONCON
Exxon Co., U.S.A.	22 Sites Groundwater Assessmen	LOS ANGELES	CA0063304	4B191015005	7394	1	4/10/05	3rd Q	00-042	DMISCEL
Holiday Inns, Inc.	Holiday Inns	LOS ANGELES	CA0053490	4B191070002	5569	3	6/10/02	2nd Q	97-095	DMISCEL
LA Co Dept of Public Works	Malibu Mesa WWRP, NPDES	MALIBU	CA0059099	4B190107048	6599	1	3/10/99	2nd Q	94-027	DDOMEST
Los Angeles County MTA	Metro Lines-Segments 2b & 3	LOS ANGELES	CA0059714	4B192515001	6763	1	4/10/02	3rd Q	97-050	HCNWTRS
Mark Wilshire Apt Tower	Los Angeles Apartment Bldg	LOS ANGELES	CA0053091	4B191019001	5839	3	6/10/02	2nd Q	97-092	DNONCON
Mobil Oil Corp.	Tank Leak-Mobil Ss#18-LDM	LOS ANGELES	CA0064262	4B192079026	8041	3	4/10/04	3rd Q	99-038	DCNWTRS
Pine Realty, Inc.	Gateway West Bldg, La	LOS ANGELES	CA0053287	4B191067001	5854	3	7/10/02	2nd Q	97-094	DMISCEL
Pivotal Century Plaza Hotel	Century Plaza Hotel & Tower	LOS ANGELES	CA0055638	4B191080001	5144	3	7/10/02	2nd Q	97-096	DMISCEL
Redondo Beach, City of	Seaside Lagoon	REDONDO BEACH	CA0064297	4B190143001	8034	3	6/10/04	2nd Q	99-057	DMISCEL
RMR Properties	Rmr Properties	LOS ANGELES	CA0054615	4B191086001	5881	3	6/10/02	2nd Q	97-100	DMISCEL
Salvation Army, The	Red Shield Yth & Community Ctr	LOS ANGELES	CA0055409	4B191016001	0565	3	6/10/02	2nd Q	97-091	DMISCEL
Santa Monica, City Of	Santa Monica Water Trt. Plant	LOS ANGELES	CA0054101	4B190122001	4904	2	7/10/05	2nd Q	00-075	DFILBRI
Stocker Resources, Inc.	Inglewood Oil Fd, Baldwin Hills	LOS ANGELES	CA0057827	4B192113018	6240	2	3/10/99	3rd Q	94-028	DSTORMS
University Of Southern Calif.	University Park Swimming Pool	LOS ANGELES	CA0054453	4B191035003	5451	3	6/10/02	4th Q	97-093	DMISCEL
UNOVA, Inc.	UNOVA, Inc.	BEVERLY HILLS	CA0055786	4B191112001	5656	3	5/10/98	4th Q	93-031	DNONCON

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
West Basin Municipal Water Dis	West Basin WWRP, NPDES	EL SEGUNDO	CA0063401	4B190137001	7449	3	5/10/05	2nd Q	00-091	DDOMEST
West Basin Municipal Water Dis	Carson Regional WRP	CARSON	CA0064246	4B190137004	7972	3	4/10/00	2nd Q	99-014	DMISCEL
general permits										
100 N. La Cienega Part Lawry's	GW-Lawry's Prime Rib Restauran	BEVERLY HILLS	CAG834001	4B196000051	7153	2	4/10/02	3rd Q	97-046	DMISCEL
100 N. La Cienega Part Lawry's	GW-Lawry's Prime Rib Restauran	BEVERLY HILLS	CAG994001	4B196000051	7153	3	4/10/02	4th Q	97-045	DMISCEL
1800 Rosecrans Partners, LLC	Former Fairchild Controls	MANHATTAN BEACH	CAG914001	4B196800019	7984	2	4/10/02	2nd Q	97-044	DMISCEL
331 North Naple LLC	Gw-Office Building	BEVERLY HILLS	CAG994001	4B196000284	7738	3	4/10/02	4th Q	97-045	DMISCEL
5055 Wilshire Limited Partner	5055 Wilshire Limited	LOS ANGELES	CAG994001	4B196000021	7078	3	4/10/02	4th Q	97-045	DMISCEL
585 North Rossmore, Ltd.	Gw-585 North Rossmore, Ltd.	LOS ANGELES	CAG994001	4B196000237	6958	3	4/10/02	4th Q	97-045	DMISCEL
Allied Signal Aerospace	Sepulveda Site	LOS ANGELES	CAG914001	4B196800022	8032	2	4/10/02	2nd Q	97-044	DCNWTRS
Amir Development Co.	Wilshire/Carson Office Build	BEVERLY HILLS	CAG994001	4B196000357	6688	3	4/10/02	4th Q	97-045	DMISCEL
Anti-Defamation League	Office Building	LOS ANGELES	CAG994001	4B196000359	6740	3	4/10/02	4th Q	97-045	DMISCEL
Arco Petroleum Products Co.	Tank Leak-Arco Station #1507	HOLLYWOOD	CAG834001	4B196600014	7282	2	4/10/02	3rd Q	97-046	HCNWTRS
Arden Realty Group, Inc.	Comstock Building	LOS ANGELES	CAG994001	4B196000416	6927	3	4/10/02	4th Q	97-045	DMISCEL
Arden Realty Group, Inc.	New Wilshire Bldg.	LOS ANGELES	CAG994001	4B196000362	6806	3	4/10/02	4th Q	97-045	DMISCEL
Atria West	Gw-Office Building East	LOS ANGELES	CAG994001	4B196000013	7070	3	4/10/02	4th Q	97-045	DMISCEL
Atria West	Gw-Office Building West	LOS ANGELES	CAG994001	4B196000014	7071	3	4/10/02	4th Q	97-045	DMISCEL
B. N. Y. California Inc.	Gw-B. N. Y. California Inc.	BEVERLY HILLS	CAG994001	4B196000016	7073	3	4/10/02	4th Q	97-045	DMISCEL
Bemard Cohen	Former Pierce Service Station	LOS ANGELES	CAG834001	4B196600114	7851	2	4/10/02	3rd Q	97-046	DMISCEL
Beverly Connection, Ltd.	Shopping Mall	LOS ANGELES	CAG994001	4B196000363	6845	3	4/10/02	4th Q	97-045	DMISCEL
Beverly Hills, City Of	Gw-City Of Beverly Hills	BEVERLY HILLS	CAG994001	4B196000142	7400	3	4/10/02	4th Q	97-045	DMISCEL
Beverly Hills, City Of	Site "A"South Parking Struct	BEVERLY HILLS	CAG994001	4B196000356	6684	3	4/10/02	4th Q	97-045	DMISCEL
Braille Institute Of America	Gw-Braille Institute Of Americ	LOS ANGELES	CAG994001	4B196000131	7364	3	4/10/02	4th Q	97-045	DMISCEL
California Fed. Enterprises	The Wilshire	LOS ANGELES	CAG994001	4B196000367	6881	3	4/10/02	4th Q	97-045	DMISCEL
Caltrans	Santa Monica Bay Watershed	LOS ANGELES	CAG994001	4B196000288	7733	3	4/10/02	4th Q	97-045	DMISCEL
Capital Salvage	Capital Salvage	LOS ANGELES	CAG994003	4B196400032	5852	3	5/10/03	2nd Q	98-055	DMISCEL
Casden Properties, Inc.	Park La Brea, Parcel A	LOS ANGELES	CAG994002	4B196100055	8159	3	4/10/02	3rd Q	97-043	DCNWTRS
Casden Properties, Inc.	Park La Brea, Parcel C	LOS ANGELES	CAG994002	4B196100042	8132	3	4/10/02	3rd Q	97-043	DCNWTRS
CBS, Inc. Television City	Gw2-Cbs, Inc.	LOS ANGELES	CAG994002	4B196100007	7275	3	4/10/02	3rd Q	97-043	DMISCEL
Cedars-Sinai Medical Center	Cedars-Sinai Medical Cente	LOS ANGELES	CAG994001	4B196000515	8106	3	4/10/02	4th Q	97-045	DMISCEL
Cedars-Sinai Medical Center	Cedars-Sinai Medical Cente	LOS ANGELES	CAG994001	4B196000236	5840	3	4/10/02	4th Q	97-045	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Cedars-Sinai Medical Center	Cedars-Sinai Medical Cente	LOS ANGELES	CAG994002	4B196100010	7814	3	4/10/02	3rd Q	97-043	DMISCEL
Center For Early Education	VOC-Center For Early Education	LOS ANGELES	CAG914001	4B196800010	6832	2	4/10/02	2nd Q	97-044	HCNWTRS
Center West	Center West	LOS ANGELES	CAG994001	4B196000361	6795	3	4/10/02	4th Q	97-045	DMISCEL
Channel Gateway L.P.	Gw-Residential Condominiums	LOS ANGELES	CAG994001	4B196000314	7799	3	4/10/02	4th Q	97-045	DMISCEL
Charnock LLP	Charnock Wellfield LLP	LOS ANGELES	CAG834001	4B196600121	7912	2	4/10/02	3rd Q	97-046	HCNWTRS
Children's Hospital Los Angele	Children's Hospital	LOS ANGELES	CAG994001	4B196000103	7299	3	4/10/02	4th Q	97-045	DMISCEL
Clark - Swall Ltd.	Clark-Swall Ltd.	LOS ANGELES	CAG994001	4B196000417	7003	3	4/10/02	4th Q	97-045	DMISCEL
Coastfed Properties	Coastfed Properties	BEVERLY HILLS	CAG994001	4B196000421	6733	3	4/10/02	4th Q	97-045	DMISCEL
Cochran Property Corp.	Cochran Ave. Apt	LOS ANGELES	CAG994001	4B196000337	6979	3	4/10/02	4th Q	97-045	DMISCEL
Copperfield Investment & Devel	Gw-Wilshire-Hignland Bldg.	LOS ANGELES	CAG994001	4B196000239	5856	3	4/10/02	4th Q	97-045	DMISCEL
CWD Cloverdale Ii Associates	Gw-328 Cloverdale Apts	LOS ANGELES	CAG994001	4B196000242	7000	3	4/10/02	4th Q	97-045	DMISCEL
Delta Towers Joint Venture	Century Plaza Towers, Offices	LOS ANGELES	CAG994001	4B196000408	5835	3	4/10/02	4th Q	97-045	DMISCEL
Douglas Emmett Realty Advisors	One Westwood- Douglas Emmett R	LOS ANGELES	CAG994001	4B196000540	8129	3	4/10/02	4th Q	97-045	IMISCEL
Douglas, Emmett & Co.	Wilshire Landmark II Building	LOS ANGELES	CAG994001	4B196000420	6837	3	4/10/02	4th Q	97-045	DMISCEL
ExxonMobil Corporation	Former Exxon Station 7-7221	LOS ANGELES	CAG834001	4B196600130	8146	2	4/10/02	3rd Q	97-046	DCNWTRS
Fansteel, Inc.	Precision Sheet Metal	LOS ANGELES	CAG914001	4B196800018	7983	2	4/10/02	2nd Q	97-044	DMISCEL
G & L Realty Corp.	Office Building Parking Garage	BEVERLY HILLS	CAG994001	4B196000365	6848	3	4/10/02	4th Q	97-045	DMISCEL
George & Erika Kabor Family Tr	La Cienega Center	BEVERLY HILLS	CAG994002	4B196100025	7938	3	4/10/02	3rd Q	97-043	DMISCEL
Goldrich & Kest Management Co.	GW-Museum Terrace Apartment	LOS ANGELES	CAG994001	4B196000339	6748	3	4/10/02	4th Q	97-045	DMISCEL
Gramercy Apartment Limited Par	Gw-Gramercy Apartment	LOS ANGELES	CAG994001	4B196000075	7233	3	4/10/02	4th Q	97-045	DMISCEL
Greenwood And Co.	Gw-Cotner Plaza	LOS ANGELES	CAG994001	4B196000129	7235	3	4/10/02	4th Q	97-045	DMISCEL
Hansohl Healthland	Tank Leak-Hansohl Healthland	LOS ANGELES	CAG834001	4B196600039	7389	2	4/10/02	3rd Q	97-046	HCNWTRS
Holt Regency / Daniel Rafalian	Gw-1200 Holt Ave. Condo	LOS ANGELES	CAG994001	4B196000025	7119	3	4/10/02	4th Q	97-045	DMISCEL
House Ear Institute	Gw2-House Ear Institute	LOS ANGELES	CAG994002	4B196100004	6946	3	4/10/02	3rd Q	97-043	DMISCEL
HPG Management	Gw-618 Detroit Apts.	LOS ANGELES	CAG994001	4B196000256	7001	3	4/10/02	4th Q	97-045	DMISCEL
HPG Management	Gw1-616 S. Burnside Apartment	LOS ANGELES	CAG994001	4B196000235	6955	3	4/10/02	4th Q	97-045	DMISCEL
HPG Management	Gw2-360 S. Detroit Apartment	LOS ANGELES	CAG994002	4B196100006	7091	3	4/10/02	3rd Q	97-043	DMISCEL
HPG Management	Gw2-Hancock Park Place Apts	LOS ANGELES	CAG994002	4B196100005	7072	3	4/10/02	3rd Q	97-043	DMISCEL
Huntley Drive Apartment	Huntley Drive Apartment	LOS ANGELES	CAG994001	4B196000283	7728	3	4/10/02	4th Q	97-045	DMISCEL
Hy - Max Building Corp.	Oakhurst Condo.	BEVERLY HILLS	CAG994001	4B196000401	7891	3	4/10/02	4th Q	97-045	DMISCEL
Il Mook Kang	Gw-Maplewood Apts.	LOS ANGELES	CAG994001	4B196000247	7004	3	4/10/02	4th Q	97-045	DMISCEL

R0026723

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Institute Plaza	Gw-Institute Plaza	LOS ANGELES	CAG994001	4B196000053	7154	3	4/10/02	4th Q	97-045	DMISCEL
IRISH CONSTRUCTION	Playa Del Rey Residential Area	PLAYA DEL REY	CAG994001	4B196000543	8176	3	4/10/02	4th Q	97-045	IMISCEL
JMB Group Trust III	Century Park Plaza	LOS ANGELES	CAG994001	4B196000514	8105	3	4/10/02	4th Q	97-045	DMISCEL
K-G Properties	Gw-K-G Properties	LOS ANGELES	CAG994001	4B196000018	7075	3	4/10/02	4th Q	97-045	DMISCEL
L. Flynt, Ltd.	Great Western Savings Center	BEVERLY HILLS	CAG994001	4B196000348	5690	3	4/10/02	4th Q	97-045	DMISCEL
LA City Bureau of Sanitation	Marina Interceptor Sewer Line	LOS ANGELES	CAG994001	4B196000517	8110	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Gw-Hollyhills Drain Unit 4	LOS ANGELES	CAG994001	4B196000211	7600	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Gw-Hollyhills Drain Unit 5	LOS ANGELES	CAG994001	4B196000212	7601	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 1	EL SEGUNDO	CAG994001	4B196000351	6092	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 2	MANHATTAN BEACH	CAG994001	4B196000352	6093	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 3&4	MANHATTAN BEACH	CAG994001	4B196000353	6094	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 5	HERMOSA BEACH	CAG994001	4B196000354	6096	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 6	REDONDO BEACH	CAG994001	4B196000410	6097	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 7	REDONDO BEACH	CAG994001	4B196000411	6098	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 8	REDONDO BEACH	CAG994001	4B196000412	6099	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	West Coast Barrier Proj, 9	EL SEGUNDO	CAG994001	4B196000415	6778	3	4/10/02	4th Q	97-045	DMISCEL
Las Virgenes MWD	Gw-Tapia Groundwater Discharge	CALABASAS	CAG994001	4B196000037	7128	3	4/10/02	4th Q	97-045	DMISCEL
Laxfuel Corp.	Tank Leak-Laxfuel Corp.	LOS ANGELES	CAG834001	4B196600100	7568	2	4/10/02	3rd Q	97-046	HCNWTRS
Le Montrose Hotel	Gw2-Le Montrose Hotel	WEST (BR. P.O.NAME FOR WEST HOLLYWOOD)	CAG994002	4B196100008	7649	3	4/10/02	3rd Q	97-043	DMISCEL
Los Angeles City of DWP	Stone Hollywood Trunk Line - 3	LOS ANGELES	CAG674001	4A196300106	8073	3	4/10/02	2nd Q	97-047	IMISCEL
Los Angeles City of DWP	Stone Hollywood Trunk Line - 4	LOS ANGELES	CAG674001	4B196300099	7934	3	4/10/02	2nd Q	97-047	DMISCEL
Los Angeles City of DWP	Franklin Reservoir	LOS ANGELES	CAG994001	4B196000434	7937	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles City of DWP	Hollywood Reservior	LOS ANGELES	CAG994001	4B196000269	7696	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles City of DWP	Stone Hollywood Trunk Line - 3	LOS ANGELES	CAG994001	4B196000505	8074	3	4/10/02	4th Q	97-045	IMISCEL
Los Angeles City of DWP	Stone Hollywood Trunk Line - 4	LOS ANGELES	CAG994001	4B196000470	7935	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles City Of Muni. Aud.	Los Angeles Convention Center	LOS ANGELES	CAG994003	4B196400033	5900	3	5/10/03	2nd Q	98-055	DMISCEL
Los Angeles County MTA	Tank Leak-Division 7	WEST (BR. P.O.NAME FOR WEST HOLLYWOOD)	CAG834001	4B196600111	7141	2	4/10/02	3rd Q	97-046	HCNWTRS
Los Angeles County Muse.Of Nat	George C Page Museum	LOS ANGELES	CAG994002	4B196100056	6739	3	4/10/02	3rd Q	97-043	IMISCEL
Los Angeles County San Dist	Calabasas Landfill	AGOURA HILLS	CAG994001	4B196000293	7749	3	4/10/02	4th Q	97-045	DMISCEL

R0026724

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Los Angeles Free Clinic Inc.	Los Angeles Free Clinic Inc.	LOS ANGELES	CAG994001	4B196000364	6846	3	4/10/02	4th Q	97-045	DMISCEL
Macerich Marina Limited Partne	Gw-Marina Market Place	MARINA DEL REY	CAG994001	4B196000167	6834	3	4/10/02	4th Q	97-045	DMISCEL
Malibu, City Of	Big Rock Mesa Drainage Facilit	MALIBU	CAG994001	4B196000419	6896	3	4/10/02	4th Q	97-045	DMISCEL
Maple Associates, Ltd	407 North Maple Drive	BEVERLY HILLS	CAG994001	4B196000544	8180	3	4/10/02	4th Q	97-045	IMISCEL
Marsh Holtzman	Gw-Wilshire Place	LOS ANGELES	CAG994001	4B196000137	7615	3	4/10/02	4th Q	97-045	DMISCEL
Masselin Manor	Masselin Manor Apartment	LOS ANGELES	CAG994001	4B196000334	6789	3	4/10/02	4th Q	97-045	DMISCEL
Medical Landmark Associates	Gw-San Vicente Convalescent	LOS ANGELES	CAG994001	4B196000171	7496	3	4/10/02	4th Q	97-045	DMISCEL
Mercury Casualty Company	Home Office Buliding	LOS ANGELES	CAG994001	4B196000332	6714	3	4/10/02	4th Q	97-045	DMISCEL
Metropolitan Water Dist. Of SC	Venice Power Plant	LOS ANGELES	CAG994003	4B196400035	7589	3	5/10/03	2nd Q	98-055	DMISCEL
Miotel Hotel	VOC-HOTEL SOFITEL LOS ANGELES	LOS ANGELES	CAG914001	4B196800009	6847	2	4/10/02	2nd Q	97-044	HCNWTRS
Mobil Oil Corp.	Tank Leak-Mobil Ss#11-Fx5	CULVER CITY	CAG834001	4B196600051	7425	2	4/10/02	3rd Q	97-046	HCNWTRS
Mobil Oil Corp.	Tank Leak-Mobil Ss#18-LDM	LOS ANGELES	CAG834001	4B196600102	7783	2	4/10/02	3rd Q	97-046	HCNWTRS
MPI, Ltd.	Gw-Mpi, Ltd.	BEVERLY HILLS	CAG994001	4B196000200	7573	3	4/10/02	4th Q	97-045	DMISCEL
N & R Hayworth Property	N & R Hayworth Property	LOS ANGELES	CAG994001	4B196000372	6987	3	4/10/02	4th Q	97-045	DMISCEL
NPS Management Corp.	West Hollywood Facility	WEST (BR. P.O.NAME FOR WEST HOLLYWOOD)	CAG994002	4B196100003	6976	3	4/10/02	3rd Q	97-043	DMISCEL
One Haemet Institute	Office-1030 Robertson Blvd. La	LOS ANGELES	CAG914001	4B196800011	6902	2	4/10/02	2nd Q	97-044	HCNWTRS
Orlando-Melrose Place Lofts	Orlando-Melrose Place Lofts	LOS ANGELES	CAG994002	4B196100043	8138	3	4/10/02	3rd Q	97-043	IMISCEL
PacificTheatres Corp.	Robertson Plaza	LOS ANGELES	CAG994001	4B196000409	5858	3	4/10/02	4th Q	97-045	DMISCEL
Panda Estate Investment, Inc.	Doheny Estates	BEVERLY HILLS	CAG994001	4B196000370	6975	3	4/10/02	4th Q	97-045	DMISCEL
Paramount Pictures Inc.	Marathon Office Building	LOS ANGELES	CAG994001	4B196000077	7234	3	4/10/02	4th Q	97-045	DMISCEL
Park La Brea	Park La Brea	LOS ANGELES	CAG994001	4B196000081	7243	3	4/10/02	4th Q	97-045	DMISCEL
Park Place Terrace Limited	Gw-Part Place Terrace	LOS ANGELES	CAG994001	4B196000080	7242	3	4/10/02	4th Q	97-045	DMISCEL
Pepperdine University	Gulls Way	MALIBU	CAG994001	4B196000224	7635	3	4/10/02	4th Q	97-045	DMISCEL
Peter Georgeanni	Gw-753 N. Wilcox Apts.	LOS ANGELES	CAG994001	4B196000238	6959	3	4/10/02	4th Q	97-045	DMISCEL
Playa Capital Co., LLC	Tank Leak-Playa Vista Site	LOS ANGELES	CAG834001	4B196600119	6839	2	4/10/02	3rd Q	97-046	HCNWTRS
Playa Capital Co., LLC	Gw-Playa Vista Development Pro	LOS ANGELES	CAG994001	4B196000243	7648	3	4/10/02	4th Q	97-045	DMISCEL
PMG, Inc.	Gw-Tiffany Court Apts.	LOS ANGELES	CAG994001	4B196000234	6749	3	4/10/02	4th Q	97-045	DMISCEL
Preferred Realty Advisors Inc.	GW - Lake View Apartments	LOS ANGELES	CAG994001	4B196000335	6835	3	4/10/02	4th Q	97-045	DMISCEL
Prentiss Properties Ltd. Inc.	Office Building, La	LOS ANGELES	CAG994001	4B196000414	6705	3	4/10/02	4th Q	97-045	DMISCEL
RealTech, Inc.	Maple Plaza	BEVERLY HILLS	CAG994001	4B196000358	6704	3	4/10/02	4th Q	97-045	DMISCEL

R0026725

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Reno Apartments	GW - Reno Apartments	LOS ANGELES	CAG994001	4B196000336	6900	3	4/10/02	4th Q	97-045	DMISCEL
Roman Catholic Archbishop L.A.	University Catholic Center	LOS ANGELES	CAG994001	4B196000342	7836	3	4/10/02	4th Q	97-045	DMISCEL
S. K. Management	Gw-Apartment At Detroit St.	LOS ANGELES	CAG994001	4B196000007	7061	3	4/10/02	4th Q	97-045	DMISCEL
S. K. Management	The Monet	LOS ANGELES	CAG994001	4B196000008	7062	3	4/10/02	4th Q	97-045	DMISCEL
Santa Monica,City Of	Charnock Mun. Water Wellfield	LOS ANGELES	CAG834001	4B196600113	7841	2	4/10/02	3rd Q	97-046	HCNWTRS
Santa Monica,City Of	Moss Ave. Pump Station	SANTA MONICA	CAG994001	4B196000384	7852	3	4/10/02	4th Q	97-045	DMISCEL
Santa Monica,City Of	PCH Sewer Replacement	SANTA MONICA	CAG994001	4B196000503	8071	3	4/10/02	4th Q	97-045	DMISCEL
Santee Dairies, Inc.	Copeland Beverage Group	LOS ANGELES	CAG994003	4B196400031	2214	3	5/10/03	2nd Q	98-055	DMISCEL
Shapiro, Gary,Evelyn & Leonard	Gw-Tiger Co.	LOS ANGELES	CAG994001	4B196000020	7077	3	4/10/02	4th Q	97-045	DMISCEL
Shell Oil Products Co.	Tank Leak-Shell Oil Gasoline S	WEST (BR. P.O.NAME FOR WEST HOLLYWOOD)	CAG834001	4B196600112	7086	2	4/10/02	3rd Q	97-046	HCNWTRS
Shorenstein Co., L.P.	Wilshire Rodeo Plaza	BEVERLY HILLS	CAG994001	4B196000355	6679	3	4/10/02	4th Q	97-045	DMISCEL
Shuwa Investment Co.	1900-01 Avenue Of The Stars	LOS ANGELES	CAG994001	4B196000349	5850	3	4/10/02	4th Q	97-045	DMISCEL
Sikh Study Circle, Inc.	Gw-Sikh Study Circle, Inc.	LOS ANGELES	CAG994001	4B196000249	7693	3	4/10/02	4th Q	97-045	DMISCEL
Sony Pictures Entertainment	Gw-The Culver Studios	CULVER CITY	CAG994002	4B196100019	7567	3	4/10/02	3rd Q	97-043	DMISCEL
Southern California Water Co.	Charnock Plant	LOS ANGELES	CAG994002	4B196100018	7360	3	4/10/02	3rd Q	97-043	DMISCEL
Southern California Water Co.	Sentney Filtration Plant	CULVER CITY	CAG994002	4B196100030	7994	3	4/10/02	3rd Q	97-043	DMISCEL
Star Property Fund, LP	Star Property Fund, LP	BEVERLY HILLS	CAG994001	4B196000371	6978	3	4/10/02	4th Q	97-045	DMISCEL
State Farm Mutual Auto Ins Co	Insurance Office, Westlake Vil	WESTLAKE VILLAGE	CAG994003	4B196400034	5842	3	5/10/03	2nd Q	98-055	DMISCEL
Steve P. Rados, Inc.	Sunset Pumping Plant	LOS ANGELES	CAG994001	4B196000312	7787	3	4/10/02	4th Q	97-045	DMISCEL
Temple Beth Am	Gw-Temple Beth Am	LOS ANGELES	CAG994001	4B196000067	7309	3	4/10/02	4th Q	97-045	DMISCEL
The Korean Times Los Angeles	Fremont Plaza	LOS ANGELES	CAG994001	4B196000413	6682	3	4/10/02	4th Q	97-045	DMISCEL
Third Fairfax, LLC	Gw-K-Mart	LOS ANGELES	CAG994001	4B196000233	7646	3	4/10/02	4th Q	97-045	DMISCEL
Tishman Speyer Properties	The Tower	LOS ANGELES	CAG994001	4B196000360	6788	3	4/10/02	4th Q	97-045	DMISCEL
TMC Realty	Ticketmaster Building	WEST (BR. P.O.NAME FOR WEST HOLLYWOOD)	CAG994001	4B196000388	6685	3	4/10/02	4th Q	97-045	DMISCEL
Tooley & Co.	Corp. Headquarters	BEVERLY HILLS	CAG994001	4B196000369	6904	3	4/10/02	4th Q	97-045	DMISCEL
Topa Management Corp.	Gateway East Office Bldg, La	LOS ANGELES	CAG994001	4B196000350	5853	3	4/10/02	4th Q	97-045	DMISCEL
Tosco / 76 Products Co.	Tank Leak-Unocal Ss #1715	LOS ANGELES	CAG834001	4B196600075	6897	2	4/10/02	3rd Q	97-046	HCNWTRS
Transamerica Senior Living,Inc	Beverly Hills Clark Plaza	BEVERLY HILLS	CAG994001	4B196000525	8107	3	4/10/02	4th Q	97-045	IMISCEL
Two Calif Plaza/Arden Realty	Tank Leak-Arden Realty Inc.	BEVERLY HILLS	CAG834001	4B196600044	7406	2	4/10/02	3rd Q	97-046	HCNWTRS

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2003/2004 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Two Rodeo Associates	Two Rodeo Associates	BEVERLY HILLS	CAG994001	4B196000373	7002	3	4/10/02	4th Q	97-045	DMISCEL
Unisys Corporation	VOC-Memorex Corp	WESTLAKE VILLAGE	CAG914001	4B196800008	6723	2	4/10/02	2nd Q	97-044	HCNWTRS
University of California LA	University of California LA	LOS ANGELES	CAG994001	4B196000532	8151	3	4/10/02	4th Q	97-045	
Unocal Corp.	Tank Leak-Unocal Ss #2124	LOS ANGELES	CAG834001	4B196600010	7619	2	4/10/02	3rd Q	97-046	HCNWTRS
Unocal Corp.	Tank Leak-Unocal Ss #5894	RANCHO PALOS VERDES	CAG834001	4B196600110	7816	2	4/10/02	3rd Q	97-046	HCNWTRS
Urban Retail Property	Century City Shopping Center	LOS ANGELES	CAG994001	4B196000407	5834	3	4/10/02	4th Q	97-045	DMISCEL
Villa Marina East Board of Dir	Villa Marina East V	MARINA DEL REY	CAG994001	4B196000402	7892	3	4/10/02	4th Q	97-045	DMISCEL
Water Repenishment Dist Of S.C	South Torrance Test Wells	TORRANCE	CAG994001	4B196000386	7861	3	4/10/02	4th Q	97-045	DMISCEL
W-B Ltd	GW-12100 Wilshire Blvd.	LOS ANGELES	CAG994001	4B196000297	7754	3	4/10/02	4th Q	97-045	DMISCEL
Wells Fargo Bank	Nc-Data Processing Center	LOS ANGELES	CAG994003	4B196400002	6641	3	5/10/03	2nd Q	98-055	DNONCON
West Basin Municipal Water Dis	West Basin Water Recycling	EL SEGUNDO	CAG674001	4B196300039	7492	3	4/10/02	2nd Q	97-047	DMISCEL
Wilshire Borgata Owner Assoc.	Gw-60 Units Condominium	LOS ANGELES	CAG994001	4B196000161	7465	3	4/10/02	4th Q	97-045	DMISCEL
Wilshire Owners Association	Wilshire Owners Association	LOS ANGELES	CAG994001	4B196000366	6879	3	4/10/02	4th Q	97-045	DMISCEL
Wilshire West Executive Center	Wilshire West Executive Center	LOS ANGELES	CAG994001	4B196000422	6953	3	4/10/02	4th Q	97-045	DMISCEL
Wilshire West Partners	Gw-Wilshire Renaissance Apts.	LOS ANGELES	CAG994002	4B196100020	6977	3	4/10/02	3rd Q	97-043	DMISCEL
World Oil Marketing Co.	Tank Leak-Station 16	SANTA MONICA	CAG834001	4B196600076	7651	2	4/10/02	3rd Q	97-046	HCNWTRS
World Oil Marketing Co.	Tank Leak-World Oil Marketing2	LOS ANGELES	CAG834001	4B196600101	7788	2	4/10/02	3rd Q	97-046	HCNWTRS
World Oil Marketing Co.	World Oil Station No. 62	BEVERLY HILLS	CAG834001	4B196600115	7860	2	4/10/02	3rd Q	97-046	HCNWTRS
Writers Guild Of America West	Gw-Fairfax Plaza	LOS ANGELES	CAG994001	4B196000153	7454	3	4/10/02	4th Q	97-045	DMISCEL

*General permit dischargers will be reviewed and may not be "renewed" but allowed to continue with enrollment

CAG674001	3
CAG834001	20
CAG914001	7
CAG994001	114
CAG994002	16
CAG994003	6

DCNWTRS	7
DCONTAC	1
DDOMEST	2
DDOMIND	3
DFILBRI	1
DMISCEL	142
DNONCON	5
DPROCESS	2
DSTORMS	1
HCNWTRS	22
HSTORMS	1
IMISCEL	8

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
LOS ANGELES RIVER WATERSHED										
majors										
Burbank, City Of Public Works	Burbank WWRP, NPDES	BURBANK	CA0055531	4B190101001	4424	1	5/10/03	1st Q	98-052	DDOMIND
LA City Bureau of Sanitation	L.A.-Glendale WWRP, NPDES	LOS ANGELES	CA0053953	4B190106001	5675	1	5/10/03	1st Q	98-047	DDOMIND
LA City Bureau of Sanitation	Tillman WWRP, NPDES	VAN NUYS	CA0056227	4B190106004	5695	1	5/10/03	1st Q	98-046	DDOMIND
Las Virgenes MWD	Tapia WWRP, NPDES	CALABASAS	CA0064271	4B191040004	8059	1	11/15/01	1st Q	99-066	DDOMEST
Southern California Edison	Dominguez Hills Fuel Oil Fac	COMPTON	CA0052949	4B192111004	5841	3	4/10/04	2nd Q	99-043	DMISCEL
The Boeing Company	Rocketdyne Div. - Santa Susana	SIMI HILLS	CA0001309	4B562013002	6027	1	5/10/03	2nd Q	98-051	DSTORMS
minors										
3M Pharmaceuticals	3M Pharmaceuticals	NORTHRIDGE (NORTH LOS ANGELES)	CA0063312	4B192594001	7482	2	4/10/03	1st Q	98-033	HCNWTRS
Arco Terminal Services Corp	East Hynes Facility	LONG BEACH	CA0059561	4B192010016	6710	3	2/10/02	2nd Q	97-019	DSTORMS
Bank Of America	Nt & Sa L.A. Data Center	LOS ANGELES	CA0057690	4B192475001	6203	2	8/10/02	3rd Q	97-126	DMISCEL
Celotex Corporation	Asphalt Roofing Mfg, La	LOS ANGELES	CA0001899	4B192355001	0642	2	11/10/03	3rd Q	98-097	DSTORMS
Chevron U.S.A. Inc.	Van Nuys Terminal	VAN NUYS	CA0059293	4B192113025	6659	3	3/10/01	2nd Q	96-018	DSTORMS
Coltec Industries Inc.	Former Menasco Aerosystem Faci	BURBANK	CA0064319	4B191318001	8044	3	9/16/04	2nd Q	99-088	DCNWTRS
Consolidated Drum Recondition	Oil Drum Recycling, South Gate	SOUTH GATE	CA0059242	4B192178001	6637	3	2/10/02	3rd Q	97-024	DSTORMS
Dial Corp, The	Southwest Grease Business	COMMERCE	CA0062022	4B192545001	6984	3	4/10/04	3rd Q	99-045	DSTORMS
Edington Oil Co.	Long Beach Refinery - Rainfall	LONG BEACH	CA0057363	4B192326003	6181	2	11/10/03	2nd Q	98-095	DSTORMS
Exxon Co., U.S.A.	Exxon Company U.S.A.	RANCHO DOMINGUEZ	CA0058971	4B192134001	6522	3	5/10/04	4th Q	99-058	DSTORMS
Exxon Co., U.S.A.	22 Sites Groundwater Assessmen	LOS ANGELES	CA0063304	4B191015005	7394	1	4/10/05	2nd Q	00-042	DMISCEL
Filtrol Corp.	Filtrol Corp.	LOS ANGELES	CA0057886	4B192488001	6242	2	3/10/02	2nd Q	97-056	DSTORMS
Kaiser Aluminum Extruded Prod.	Kaiser Aluminum Extruded Prod.	COMMERCE	CA0000892	4B192389001	6010	3	4/10/04	1st Q	99-044	DPROCES
Kaiser Marquardt, Inc.	Ramjet Testing, Van Nuys	VAN NUYS	CA0003344	4B192070001	1265	3	5/10/03	2nd Q	98-054	DCONTAC
Lincoln Avenue Water Co.	South Coulter Water Treatment	ALTADENA	CA0064068	4B191300001	7752	3	12/10/01	1st Q	97-002	DMISCEL
Los Angeles City of DWP	General Office Building	LOS ANGELES	CA0056855	4B190106035	4135	3	4/10/02	4th Q	97-054	DMISCEL
Los Angeles City of DWP	Tunnel # 105	NEWHALL	CA0064149	4B190106099	7839	3	1/10/03	4th Q	98-007	DMISCEL
Los Angeles City Of Rec&Parks	Los Angeles Zoo Griffith Park	LOS ANGELES	CA0056545	4B190106036	4551	2	5/10/03	2nd Q	98-053	DDOMEST
Los Angeles County MTA	Metro Lines-Segments 1 & 2a	LOS ANGELES	CA0064092	4B192515004	7759	1	4/10/02	1st Q	97-049	HCNWTRS
Los Angeles Turf Club	Santa Anita Park	ARCADIA	CA0064203	4B191319001	8102	3	9/10/04	1st Q	99-109	DMISCEL
Mairoll, Inc.	Voi-Shan Chatsworth	CHATSWORTH	CA0064084	4B191306001	7762	3	2/10/02	4th Q	97-016	DMISCEL
MCA / Universal City Studios	Universal City Studios	UNIVERSAL CITY (MOVIE STUDIO)	CA0002739	4B199017001	5988	3	10/10/01	4th Q	96-083	DFILBRI

R0026728

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
McWhorter Technologies, Inc.	McWhorter Technologies, Inc.	LYNWOOD	CA0063908	4B191297001	7655	2	5/10/04	2nd Q	99-053	DCNWTRS
Metropolitan Water Dist. Of SC	Rio Hondo Power Plant	SOUTH GATE	CA0059633	4B190115005	6742	3	4/10/02	3rd Q	97-051	DNONCON
Owens-Brockway Glass Container	Glass Container Div, Vernon	VERNON	CA0056464	4B192085002	6079	2	2/10/02	3rd Q	97-017	DNONCON
Pabco Paper Products	Paperboard & Carton Mfg,Vernon	VERNON	CA0057274	4B192486001	4671	3	11/10/03	3rd Q	98-098	DSTORMS
Pacific Refining Co.	Former Western Fuel Oil	SAN PEDRO	CA0064190	4B191311001	7865	2	7/10/03	4th Q	98-060	DMISCEL
Pasadena, City Of, DWP	Dept. Of Water & Power	PASADENA	CA0063355	4B190138001	7576	3	5/10/03	3rd Q	98-057	DNONCON
Sta - Lube, Inc.	Sta - Lube, Inc.	RANCHO DOMINGUEZ	CA0064025	4B191293001	7742	2	11/10/01	1st Q	96-089	DPROCES
Water Repenishment Dist Of S.C	West Coast Basin Desalter	TORRANCE	CA0064238	4B190140001	7949	3	4/10/02	2nd Q	99-042	DFILBRI
general permits										
550 S. Hope Street Associates	Gw-550 S. Hope St. Building	LOS ANGELES	CAG994001	4B196000003	7063	3	4/10/02	4th Q	97-045	DMISCEL
5th Street Properties, LLC	Trillium Towers	WOODLAND HILLS	CAG994001	4B196000398	6833	3	4/10/02	4th Q	97-045	DMISCEL
Ah Warner Center Properties	Gw-Warner Center Plaza 3	WOODLAND HILLS	CAG994001	4B196000313	7792	3	4/10/02	4th Q	97-045	DMISCEL
Alpha Therapeutic Corp	Blood Fractionation & Process	LOS ANGELES	CAG994003	4B196400043	6453	3	5/10/03	4th Q	98-055	DNONCON
Aramark Uniform Services	Former Aratex Services	LONG BEACH	CAG914001	4B196800021	7395	2	4/10/02	2nd Q	97-044	DCNWTRS
Arco Pipe Line Co.	Ht-West Hynes Pump Station	LONG BEACH	CAG674001	4B196300062	7770	3	4/10/02	3rd Q	97-047	DMISCEL
Bank Of America	Gw-Koll Mang. Services	LOS ANGELES	CAG994001	4B196000028	7099	3	4/10/02	4th Q	97-045	DMISCEL
Brytoco Engr. & Const. Co. Inc	Compton Creek Bridge	RANCHO DOMINGUEZ	CAG994001	4B196000489	8033	3	4/10/02	4th Q	97-045	IMISCEL
Burbank, City Of Public Servic	Gw-Burbank Public Service Dept	BURBANK	CAG994001	4B196000043	7132	3	4/10/02	4th Q	97-045	.DMISCEL
Burbank, City Of Public Servic	Gw2-Reservoir Forebay	BURBANK	CAG994002	4B196100009	7316	3	4/10/02	3rd Q	97-043	DMISCEL
California American Water Co.	Gw-Arlington Well # 2	LOS ANGELES	CAG994001	4B196000149	7441	3	4/10/02	4th Q	97-045	DMISCEL
California Credit Union	California Credit Union	LOS ANGELES	CAG994001	4B196000427	6882	3	4/10/02	4th Q	97-045	DMISCEL
California Water Service Co.	GW-Compton Creek Water Wells	LONG BEACH	CAG994001	4B196000311	7782	3	4/10/02	4th Q	97-045	NMISCEL
California Water Service Co.	Well # 94	LONG BEACH	CAG994001	4B196000374	7831	3	4/10/02	4th Q	97-045	DMISCEL
California Water Service Co.	Well # 97	LONG BEACH	CAG994001	4B196000442	7948	3	4/10/02	4th Q	97-045	DMISCEL
California Water Service Co.	Well #'s 15 & 16	LONG BEACH	CAG994001	4B196000375	7830	3	4/10/02	4th Q	97-045	DMISCEL
Caltrans	LA-105 Garfield/Ardis Ave.	DOWNEY	CAG914001	4B196800025	8068	2	4/10/02	2nd Q	97-044	DCNWTRS
Caltrans	Los Angeles River Watershed	LOS ANGELES	CAG994001	4B196000286	7731	3	4/10/02	4th Q	97-045	DMISCEL
Capital & Conuties U.S.A.,Inc.	Capital & Counties U.S.A.,Inc.	LOS ANGELES	CAG994001	4B196000493	6972	3	4/10/02	4th Q	97-045	HCNWTRS
CarrAmerica Realty Corp.	CarrAmerica Office Building	WOODLAND HILLS	CAG994001	4B196000474	6917	3	4/10/02	4th Q	97-045	DNONCON
Citadel Realty, Inc.	Fidelity Federal Bank Bldg.	GLENDALE	CAG994003	4B196400025	6236	3	5/10/03	4th Q	98-055	DMISCEL
Coast Packing Co.	Nc-Coast Packing Co.	VERNON	CAG994003	4B196400003	7652	3	5/10/03	4th Q	98-055	DNONCON

R0026729

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Compton Municipal Water Dept.	Municipal Water Supply Wells	COMPTON	CAG994002	4B196100044	8147	3	4/10/02	3rd Q	97-043	DMISCEL
Comerstone Suburban Office,L	First Financial plaza	ENCINO	CAG994001	4B196000399	6713	3	4/10/02	4th Q	97-045	DMISCEL
Crescenta Valley Water Distric	Water Well No. 15	VERDUGO CITY	CAG994002	4B196100059	8181	3	4/10/02	3rd Q	97-043	DMISCEL
Dba "Ultimate"	Nc-Dba "Ultimate"	LOS ANGELES	CAG994003	4B196400005	7679	3	5/10/03	4th Q	98-055	DNONCON
DTSC/England & Assoc.	Former Southland Oil Site	COMMERCE	CAG914001	4B196800033	8152	2	4/10/02	2nd Q	97-044	DCNWTRS
East Pasadena Water Co.	Water Well No. 10	PASADENA	CAG994001	4B196000550	8131	3	4/10/02	4th Q	97-045	IMISCEL
Equilon Enterprises LLC	Shell Station	LYNWOOD	CAG834001	4B196600131	8169	2	4/10/02	4th Q	97-046	DCNWTRS
Fashion Square Car Wash	Fashion Square Car Wash	SHERMAN OAKS	CAG834001	4B196600127	8081	2	4/10/02	4th Q	97-046	DCNWTRS
Former Shell SS/Equilon Enter.	Hanna's Arco	LOS ANGELES	CAG834001	4B196600019	7609	2	4/10/02	4th Q	97-046	HCNWTRS
G & K Management Co., Inc.	Gw-Grand Promenade	LOS ANGELES	CAG994001	4B196000135	7611	3	4/10/02	4th Q	97-045	DMISCEL
Glendale Adventist Med. Center	Physicians Medical Terrace	GLENDALE	CAG994003	4B196400017	7448	3	5/10/03	4th Q	98-055	DNONCON
Glendale Ii Associates, Ltd.	Nc-Glendale Galleria Office	GLENDALE	CAG994003	4B196400006	6683	3	5/10/03	4th Q	98-055	DNONCON
Glendale Memorial Hospital	Health Center	GLENDALE	CAG994003	4B196400022	6903	3	5/10/03	4th Q	98-055	DMISCEL
Grand Central Square	Gw-Parking Structure	LOS ANGELES	CAG994001	4B196000035	7127	3	4/10/02	4th Q	97-045	DMISCEL
Gross Enterprises, Inc.	Encino Exexutive Plaza	ENCINO	CAG994002	4B196100014	6722	3	4/10/02	3rd Q	97-043	DMISCEL
Home Savings	Gw-Sherman Oaks Branch	SHERMAN OAKS	CAG994001	4B196000144	7407	3	4/10/02	4th Q	97-045	DMISCEL
Interstate Brands Corp.	Tank Leak-Interstate Brands	GLENDALE	CAG834001	4B196600103	7212	2	4/10/02	4th Q	97-046	HCNWTRS
James Ratkovich Real Estate	The Pacific	LONG BEACH	CAG994001	4B196000453	6973	3	4/10/02	4th Q	97-045	DMISCEL
Jet Propulsion Laboratory	Jet Propulsion Lab.	PASADENA	CAG994001	4B196000430	7480	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Alamitos Barrier Project 1,2&3	LONG BEACH	CAG994001	4B196000501	8066	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Gw-Storm Drain Project 9037	LONG BEACH	CAG994001	4B196000182	7517	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Le Sage Avenue Drain	WOODLAND HILLS	CAG994001	4B196000425	7907	3	4/10/02	4th Q	97-045	DMISCEL
LA Co Dept of Public Works	Project 9037 Unit 4	LONG BEACH	CAG994002	4B196100058	8162	3	4/10/02	3rd Q	97-043	IMISCEL
Laeroc 1998 Income Fund, L.P.	Carbon Cannister Water Trt Sys	LOS ANGELES	CAG994003	4B196400048	6915	3	5/10/03	4th Q	98-055	DCNWTRS
Lasmo Oil & Gas Inc.	Carson Tank Farm	CARSON	CAG834001	4B196600077	7642	2	4/10/02	4th Q	97-046	HCNWTRS
Long Beach Building Materials	Long Beach Building Materials	LONG BEACH	CAG834001	4B196600128	8123	2	4/10/02	4th Q	97-046	ICNWTRS
Los Angeles City of DWP	East Valley Water Recycling Pj	SAN FERNANDO	CAG674001	4B196300089	7943	3	4/10/02	3rd Q	97-047	DMISCEL
Los Angeles City of DWP	Roscoe Tank Line No. 2	CANOGA PARK	CAG674001	4B196300097	7999	3	4/10/02	3rd Q	97-047	DMISCEL
Los Angeles City of DWP	Headwork Pilot Well Test	BURBANK	CAG914001	4B196800020	7991	2	4/10/02	2nd Q	97-044	DMISCEL
Los Angeles City of DWP	Pollock Wells Treatment Plant	LOS ANGELES	CAG914001	4B196800016	7637	2	4/10/02	2nd Q	97-044	DMISCEL
Los Angeles City of DWP	Stone Inlet Line Flow Control	SHERMAN OAKS	CAG994001	4B196000426	7909	3	4/10/02	4th Q	97-045	DMISCEL

R0026730

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Los Angeles City Of Gen. Serv.	Nc-Los Angeles City Hall	LOS ANGELES	CAG994003	4B196400008	7774	3	5/10/03	4th Q	98-055	DNONCON
Los Angeles County Parking Aut	Gw-Walt Disney Hall Parking	LOS ANGELES	CAG994001	4B196000076	7227	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles Times	Gw-Office Bldg. 145 S. Spring	LOS ANGELES	CAG994001	4B196000033	7117	3	4/10/02	4th Q	97-045	DMISCEL
Los Angeles Times	Parking Structure 205 W. 2nd.	LOS ANGELES	CAG994003	4B196400049	6994	3	5/10/03	4th Q	98-055	DMISCEL
Los Angeles Times	Parking Structure 213 S.Spring	LOS ANGELES	CAG994003	4B196400046	6854	3	5/10/03	4th Q	98-055	DMISCEL
Los Angeles Times	Parking Structure 220 S.Spring	LOS ANGELES	CAG994003	4B196400051	7013	3	5/10/03	4th Q	98-055	DMISCEL
Los Angeles Unified School Dis	Tank Leak-Los Angeles Unified	LOS ANGELES	CAG834001	4B196600066	7521	2	4/10/02	4th Q	97-046	HCNWTRS
Lubricating Specialties Co.	Lubricating Specialties Co.	VERNON	CAG994003	4B196400044	6761	3	5/10/03	4th Q	98-055	DSTORMS
Macy's West	Macy's West Glendale	GLENDALE	CAG994003	4B196400023	6224	3	5/10/03	4th Q	98-055	DMISCEL
Maguire Partners	The Gas Company Tower	LOS ANGELES	CAG994003	4B196400050	7005	3	5/10/03	4th Q	98-055	DCNWTRS
Maguire Thomas Partners	Glendale Center	GLENDALE	CAG994003	4B196400014	5755	3	5/10/03	4th Q	98-055	DNONCON
Mammoth Apartments, LLC	Mammoth Apartments	SHERMAN OAKS	CAG994001	4B196000546	8172	3	4/10/02	4th Q	97-045	IMISCEL
Metropolitan Water Dist. Of SC	Greg Avenue Power Plant	SUN VALLEY	CAG994003	4B196400029	7588	3	5/10/03	4th Q	98-055	DMISCEL
Mitsui Fudosan (U.S.A.) Inc.	Gw-Sanwa Bank Plaza	LOS ANGELES	CAG994001	4B196000324	6986	3	4/10/02	4th Q	97-045	DMISCEL
Mobil Oil Corp.	Vernon Terminal	VERNON	CAG674001	4B196300120	8160	3	4/10/02	3rd Q	97-047	IMISCEL
Mobil Oil Corp.	Tank Leak-Mobil Ss#11-Frn	ENCINO	CAG834001	4B196600097	7760	2	4/10/02	4th Q	97-046	HCNWTRS
Monrovia, City of	Well # 6	MONROVIA	CAG994001	4B196000387	7870	3	4/10/02	4th Q	97-045	DMISCEL
Newlowe Properties	Newlowe Properties	LOS ANGELES	CAG914001	4B196800012	7837	2	4/10/02	2nd Q	97-044	DMISCEL
Norwalk, City Of	Gw-G. W. Wells Nos. 3, 4, 5, 8	NORWALK	CAG994001	4B196000063	7188	3	4/10/02	4th Q	97-045	DMISCEL
One California Plaza	Gw-One California Plaza	LOS ANGELES	CAG994001	4B196000193	7560	3	4/10/02	4th Q	97-045	DMISCEL
Pacific Pipeline System, Inc.	West Hynes Station	LONG BEACH	CAG674001	4B196300115	8122	3	4/10/02	3rd Q	97-047	DMISCEL
Pico Water District	Gw-Pico Water District	PICO RIVERA	CAG994001	4B196000114	7317	3	4/10/02	4th Q	97-045	DMISCEL
Red Lion Hotel	Red Lion Hotel	GLENDALE	CAG994003	4B196400015	7353	3	5/10/03	4th Q	98-055	DNONCON
Robert Chan	B.C. Plaza	LOS ANGELES	CAG994003	4B196400047	6885	3	5/10/03	4th Q	98-055	DMISCEL
Sherman Car Inc.	Sherman Car Inc	LONG BEACH	CAG834001	4B196600126	8062	2	4/10/02	4th Q	97-046	IMISCEL
Sierracin/Sylmar Corp.	Nc-Sierracin.Sylmar Corp.	SYLMAR	CAG994003	4B196400009	6008	3	5/10/03	4th Q	98-055	DNONCON
Smith & Hricik	550 N. Brand Office Building	GLENDALE	CAG994003	4B196400018	6894	3	5/10/03	4th Q	98-055	DNONCON
Soledad Enrichment Action, Inc	Gw-W. San Fernando Courthouse	CHATSWORTH	CAG994001	4B196000093	7273	3	4/10/02	4th Q	97-045	DMISCEL
South Gate, City Of	Gw-South Gate Park Reservoir	SOUTH GATE	CAG994001	4B196000071	7295	3	4/10/02	4th Q	97-045	DMISCEL
South Gate, City Of	Gw-Well-Head Wts Const.	SOUTH GATE	CAG994001	4B196000105	7304	3	4/10/02	4th Q	97-045	DMISCEL
Southern California Edison	EPTC Pipeline (Los Angele Riv)		CAG674001	4B196300111	8096	3	4/10/02	3rd Q	97-047	IMISCEL

R0026731

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Southern California Edison	Tank Leak-Compton Service Cen.	COMPTON	CAG834001	4B196600108	7210	2	4/10/02	4th Q	97-046	HCNWTRS
Southern California Edison	GW-EDISON PIPELINE & TERMINAL	LOS ANGELES	CAG994001	4B196000322	7811	3	4/10/02	4th Q	97-045	DMISCEL
SOUTHERN CALIFORNIA GAS CO	Line120 Pipeline Relocation Pj	VAN NUYS	CAG674001	4B196300117	8155	3	4/10/02	3rd Q	97-047	IMISCEL
Southern California Gas Co.	Ht-Line 765	LONG BEACH	CAG674001	4B196300041	7501	3	4/10/02	3rd Q	97-047	DMISCEL
Southern California Water Co.	Chanslor Well	BELL	CAG994001	4B196000519	8112	3	4/10/02	4th Q	97-045	IMISCEL
Southern California Water Co.	Century Site	PARAMOUNT	CAG994002	4B196100049	8140	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Clara Site	BELL GARDENS	CAG994002	4B196100054	8145	3	4/10/02	3rd Q	97-043	NMISCEL
Southern California Water Co.	Gage Site Water Wells	BELL GARDENS	CAG994002	4B196100061	8184	3	4/10/02	3rd Q	97-043	DCNWTRS
Southern California Water Co.	Goodyear Site	LOS ANGELES	CAG994002	4B196100045	8134	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Nadeau Site	LOS ANGELES	CAG994002	4B196100052	8143	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Priory Site	BELL GARDENS	CAG994002	4B196100050	8141	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Hoffman Plant	CUDAHY	CAG994003	4B196400056	8064	3	5/10/03	4th Q	98-055	IMISCEL
Thrifty Oil Co.	Thrifty Oil Co. # 132	TARZANA	CAG834001	4B196600118	6942	2	4/10/02	4th Q	97-046	HCNWTRS
Tract 349 Mutual Water Company	Well 2 & 3 and 2 Tanks	CUDAHY	CAG994003	4B196400059	8070	3	5/10/03	4th Q	98-055	IMISCEL
Two Calif Plaza/Arden Realty	Two Calif Plaza/Equity Office	LOS ANGELES	CAG994001	4B196000027	7098	3	4/10/02	4th Q	97-045	DMISCEL
United Storm Water, Inc.	Storm Drain Cleaning I	LOS ANGELES	CAG994002	4B196100034	8024	3	4/10/02	3rd Q	97-043	DMISCEL
United Storm Water, Inc.	Storm Drain Cleaning II	LOS ANGELES	CAG994002	4B196100035	8025	3	4/10/02	3rd Q	97-043	DMISCEL
University Of Southern Calif.	Center for Health Professions	LOS ANGELES	CAG994001	4B196000450	7961	3	4/10/02	4th Q	97-045	DMISCEL
Voit Management Co., LP	Plaza Six, Warner Center	WOODLAND HILLS	CAG994001	4B196000389	6926	3	4/10/02	4th Q	97-045	DMISCEL
Walnut Park Mutual Water Co.	Well # 11	HUNTINGTON PARK	CAG994001	4B196000437	7942	3	4/10/02	4th Q	97-045	DMISCEL
Walt Disney Co., The	Riverside Bldg.	BURBANK	CAG994002	4B196100022	7922	3	4/10/02	3rd Q	97-043	DMISCEL
Warner Brothers Inc.	Warner Brothers Studio Facilit	BURBANK	CAG994003	4B196400053	8060	3	5/10/03	4th Q	98-055	IMISCEL
Warner Corporate Center	GW2-Warner Corperate Center	WOODLAND HILLS	CAG994002	4B196100001	7794	3	4/10/02	3rd Q	97-043	DMISCEL
Water Repenishment Dist Of S.C	Dominguez Monitoring Wells	WILMINGTON	CAG994001	4B196000403	7895	3	4/10/02	4th Q	97-045	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2004/2005 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Westland Investment	Central Stocker Ltd.	GLENDALE	CAG994003	4B196400011	6762	3	5/10/03	4th Q	98-055	DNONCON
World Oil Marketing Co.	Tank Leak-World Oil Marketing1	ARTESIA	CAG834001	4B196600080	7667	2	4/10/02	4th Q	97-046	HCNWTRS
WRC Properties, Inc.	Office Bldg.- 330 N. Brand	GLENDALE	CAG994003	4B196400016	7862	3	5/10/03	4th Q	98-055	DNONCON
ZERO CORP.-ZERO WEST DIVISION	ZERO CORP.-ZERO WEST DIVISION	BURBANK	CAG994001	4B196000531	7399	3	4/10/02	4th Q	97-045	DCNWTRS

*General permit dischargers will be reviewed and may not be "renewed" but allowed to continue with enrollment

CAG674001	8
CAG834001	12
CAG914001	6
CAG994001	42
CAG994002	15
CAG994003	26

DCNWTRS	11
DCONTACT	1
DDOMEST	2
DDOMIND	3
DFILBRI	2
DMISCEL	67
DNONCON	16
DPROCES	2
DSTORMS	11
HCNWTRS	11
ICNWTRS	1
IMISCEL	16
NMISCEL	2

R0026733

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2005/2006

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
SAN GABRIEL RIVER WATERSHED										
majors										
AES Alamitos, L.L.C.	Alamitos Generating Station	LONG BEACH	CA0001139	4B192111006	6113	1	5/10/05	1st Q	00-082	DPROCES
Cenco Refining Co.	Santa Fe Springs Refinery	SANTA FE SPRINGS	CA0057177	4B192093001	6154	1	4/10/05	1st Q	00-068	DSTORMS
Los Angeles City of DWP	Haynes Generating Station	LONG BEACH	CA0000353	4B193500002	2769	1	5/10/05	1st Q	00-081	DCONTAC
Los Angeles County San Dist	Pomona WWRP, NPDES	POMONA	CA0053619	4B190107019	0755	1	5/10/00	2nd Q	95-078	DDOMIND
Los Angeles County San Dist	Whittier Narrows WWRP, NPDES	EL MONTE	CA0053716	4B190107016	2848	1	5/10/00	2nd Q	95-082	DDOMIND
Los Angeles County San Dist	San Jose Creek WWRP, NPDES	WHITTIER	CA0053911	4B190107020	5542	1	5/10/00	2nd Q	95-079	DDOMIND
Los Angeles County San Dist	Los Coyotes WWRP, NPDES	CERRITOS (DAIRY VALLEY)	CA0054011	4B190107015	5059	1	5/10/00	2nd Q	95-077	DDOMIND
Los Angeles County San Dist	Long Beach WWRP, NPDES	LONG BEACH	CA0054119	4B190107014	5662	1	5/10/00	2nd Q	95-076	DDOMIND
minors										
Ball-Foster Glass Container Co	Ball Glass Container Corp.	EL MONTE	CA0000884	4B192262001	5720	3	11/10/03	1st Q	98-096	DPROCES
California Dairies Inc.	Milk Process Plant, Artesia	ARTESIA	CA0057371	4B192454001	6166	3	12/9/04	2nd Q	99-136	DMISCEL
California State University	CSU, Long Beach, Pool, Etc	LONG BEACH	CA0054267	4B190800001	2952	3	4/10/99	4th Q	94-034	DMISCEL
Covina Irrigating Co.	Treatment Plant #1	GLENDORA	CA0060577	4B192526001	6849	3	12/9/04	1st Q	99-137	DPROCES
Exxon Co., U.S.A.	22 Sites Groundwater Assessmen	LOS ANGELES	CA0063304	4B191015005	7394	1	4/10/05	1st Q	00-042	DMISCEL
Golden West Refining Co.	Santa Fe Springs Refinery	SANTA FE SPRINGS	CA0055115	4B192162001	6083	2	3/10/05	3rd Q	00-051	DSTORMS
Hemlock Mutual Water Company	Hemlock Mutual Water Company	EL MONTE	CA0059552	4B191152001	6706	3	7/10/02	4th Q	97-108	DWSHWTR
LACnty. FairHotel&Expo Complex	Fairplex	POMONA	CA0064254	4B190144001	8101	3	9/10/04	4th Q	99-107	DMISCEL
Libbey Glass Inc.	City Of Industry Facility	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CA0001821	4B192085001	2955	3	11/10/04	2nd Q	99-132	DCONTAC
Los Angeles City of DWP	Tank H, J Area, Haynes Plt. Lb	LONG BEACH	CA0056995	4B190106042	6142	3	2/10/05	3rd Q	00-028	DSTORMS
Los Angeles City of DWP	Tank A,B,C,D Area,Haynes Pl,Lb	LONG BEACH	CA0057649	4B190106007	6208	3	2/10/05	3rd Q	00-025	DSTORMS
Los Angeles City of DWP	Tank E Area, Haynes Plt, Lb	LONG BEACH	CA0057665	4B190106049	6209	3	2/10/05	3rd Q	00-026	DSTORMS
Los Angeles City of DWP	Tank F,G Area,Haynes Plt, Lb	LONG BEACH	CA0057673	4B190106050	6210	3	2/10/05	3rd Q	00-027	DSTORMS
Lubricating Specialties Co.	Pico Rivera, Oil Blending	PICO RIVERA	CA0059013	4B192127001	6521	3	4/10/02	3rd Q	97-052	DSTORMS
Metropolitan Water Dist. Of SC	Weymouth Softening&Filtration	LA VERNE	CA0057070	4B190115004	6141	3	10/28/05	3rd Q	99-102	IMISCEL
Norwalk Industries Co.	Ecology Auto Wrecking	SANTA FE SPRINGS	CA0056928	4B199032001	6041	1	5/10/02	1st Q	97-076	DSTORMS
Royal Catering	Royal Catering, El Monte	EL MONTE	CA0053392	4B191106001	5849	2	6/10/05	3rd Q	00-112	DSTORMS
SFPP, LP	Norwalk Pump Station	NORWALK	CA0063509	4B192597001	7497	1	5/10/05	1st Q	00-088	HCNWTRS

R0026734

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2005/2006 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
TRW Inc.	Ground Water Treatment	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CA0064114	4B192557004	7531	3	4/10/02	3rd Q	97-057	HCNWTRS
U.S. Gypsum Co.	U.S. Gypsum Co.	LA MIRADA	CA0063461	4B191287001	7481	2	4/10/05	2nd Q	00-066	HCNWTRS
Unocal Corp.	Former La Mirada Plant	LA MIRADA	CA0063975	4B192131031	7688	3	11/10/04	2nd Q	99-138	DCONTAC
US Navy Defense Fuel Supply Ce	Defense Fuel Supply - Norwalk	NORWALK	CA0059137	4B190705001	6572	3	10/10/04	3rd Q	99-133	DSTORMS
Wheelabrator Norwalk Energy Co	State Hospital Cogeneration Pt	NORWALK	CA0059927	4B191168001	6767	3	12/10/05	3rd Q	00-008	DNONCON
general permits										
Ashland Chemical Company	Ashland Chemical Company	SANTA FE SPRINGS	CAG914001	4B196800001	7785	2	4/10/02	4th Q	97-044	HCNWTRS
B F Goodrich Aerospace	B F Goodrich Aerospace Carbon	SANTA FE SPRINGS	CAG994003	4B196400039	7963	3	5/10/03	4th Q	98-055	DMISCEL
Bell Gardens, City Of, DPW	Gw-Domestic Water Well	BELL GARDENS	CAG994001	4B196000276	7708	3	4/10/02	4th Q	97-045	DMISCEL
Bumble Bee Seafoods, Inc.	Santa Fe Springs Facility	SANTA FE SPRINGS	CAG994003	4B196400062	6913	3	5/10/03	4th Q	98-055	DNONCON
California American Water Co.	Hall Well Site	TEMPLE CITY (RUDELL)	CAG994001	4B196000446	7957	3	4/10/02	4th Q	97-045	DMISCEL
California American Water Co.	Longden Well	SAN MARINO	CAG994001	4B196000377	7843	3	4/10/02	4th Q	97-045	DMISCEL
Caltrans	LA-105 Woodruff Ave	DOWNEY	CAG914001	4B196800026	8069	2	4/10/02	4th Q	97-044	DCNWTRS
Caltrans	Route 10 Pavement Rehab. Pj.	POMONA	CAG994001	4B195000504	8072	3	4/10/02	4th Q	97-045	DMISCEL
Caltrans	San Gabriel River Watershed	WHITTIER	CAG994001	4B196000285	7730	3	4/10/02	4th Q	97-045	DMISCEL
Carrier Corporation	VOC-Carrier Coporation	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG914001	4B196800002	7786	2	4/10/02	4th Q	97-044	HCNWTRS
Cerritos, City Of	C-5 Water Well	CERRITOS (DAIRY VALLEY)	CAG994001	4B196000538	8164	3	4/10/02	4th Q	97-045	IMISCEL
Cerritos, City Of	Gw-Cerritos Sheriff Station	CERRITOS (DAIRY VALLEY)	CAG994001	4B196000216	7604	3	4/10/02	4th Q	97-045	DMISCEL
Downey, City Of, Water Supply	Gw-Water Supply Well # 11	DOWNEY	CAG994001	4B196000148	7431	3	4/10/02	4th Q	97-045	DMISCEL
Eric Realty	VOC-Eric Realty	LA MIRADA	CAG914001	4B196800006	7798	2	4/10/02	4th Q	97-044	HCNWTRS
Fairchild Holding Corp.	Fairchild Fasteners Screwcorp	INDUSTRY (CORPORATE NAME FOR CITY OF INDUSTRY)	CAG914001	4B196800017	7980	2	4/10/02	4th Q	97-044	DMISCEL
Goulds Pumps Inc.	Goulds Pumps Inc.	INDUSTRY (CORPORATE NAME FOR CITY OF INDUSTRY)	CAG674001	4B196300092	7965	3	4/10/02	3rd Q	97-047	DMISCEL
Hamilton Standard Controls	Spectrol Electronics	INDUSTRY (CORPORATE NAME FOR CITY OF INDUSTRY)	CAG994001	4B196000436	7620	3	4/10/02	4th Q	97-045	DMISCEL
Hermetic Seal Corp.	Hermetic Seal Corp.	ROSEMEAD	CAG914001	4B196800031	7699	2	4/10/02	4th Q	97-044	HCNWTRS
Hermetic Seal Corp.	Hermetic Seal Corp.	ROSEMEAD	CAG994003	4B196400038	2937	3	5/10/03	4th Q	98-055	DMISCEL
J. A. B. Holdings, Inc.	J. A. B. Holdings	EL MONTE	CAG914001	4B196800015	7402	2	4/10/02	4th Q	97-044	DMISCEL
Jayeast Partnership	Central Plaza	CERRITOS (DAIRY VALLEY)	CAG994003	4B196400061	6914	3	5/10/03	4th Q	98-055	DCNWTRS
Kinneloa Irrigation Dist.	Gw-K3 Water Well	PASADENA	CAG994001	4B196000011	7066	3	4/10/02	4th Q	97-045	DMISCEL

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2005/2006 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
La Habra Heights Co. Water Dis	Well # 10	LA HABRA HEIGHTS	CAG994001	4B196000444	7953	3	4/10/02	4th Q	97-045	DMISCEL
La Verne, City of	Wheeler Park	LA VERNE	CAG994001	4B196000429	7914	3	4/10/02	4th Q	97-045	DMISCEL
Lansco Die Casting, Inc.	Lansco Die Casting Inc.	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG994003	4B196400058	8075	3	5/10/03	4th Q	98-055	IMISCEL
Long Beach Water Dept.	Commision 19 & 20 Water Wells	LONG BEACH	CAG994001	4B196000379	7845	3	4/10/02	4th Q	97-045	DMISCEL
Long Beach Water Dept.	Commission 21, 22, & 23 Wells	LONG BEACH	CAG994001	4B196000535	8161	3	4/10/02	4th Q	97-045	IMISCEL
Long Beach Water Dept.	Wise 1A Water Well	LONG BEACH	CAG994001	4B196000516	8088	3	4/10/02	4th Q	97-045	IMISCEL
Main San Gabriel Basin Water	Strategic Well Testing	AZUSA	CAG994001	4B196000279	7718	3	4/10/02	4th Q	97-045	DMISCEL
McKesson Corporation	VOC-Former McKesson Facility	SANTA FE SPRINGS	CAG914001	4B196800003	7789	2	4/10/02	4th Q	97-044	HCNWTRS
Montebello Land & Water Co	Well No. 14, Southeast Corner	LOS ANGELES	CAG994001	4B196000465	7988	3	4/10/02	4th Q	97-045	DMISCEL
PASADENA CITY OF	Well #59	PASADENA	CAG994001	4B196000449	7960	3	4/10/02	4th Q	97-045	DMISCEL
Pasadena, City Of, DWP	Gw-Garfield Well	PASADENA	CAG994001	4B196000042	7151	3	4/10/02	4th Q	97-045	DMISCEL
Rockview Dairies, Inc.	Gw-Potable Water Well	SOUTH GATE	CAG994001	4B196000315	7801	3	4/10/02	4th Q	97-045	DMISCEL
Rowland Water District	Well # 1	INDUSTRY (CORPORATE NAME FOR CITY OF INDUSTRY)	CAG994002	4B196100029	7978	3	4/10/02	3rd Q	97-043	DMISCEL
San Gabriel Basin WQ Authority	Whittier Narrows Early Action	SOUTH EL MONTE	CAG914001	4B196800030	8056	2	4/10/02	4th Q	97-044	DCNWTRS
San Gabriel Valley Water Co.	San Gabriel Valley Water-Pt.2	EL MONTE	CAG674001	4B196300069	7857	3	4/10/02	3rd Q	97-047	DMISCEL
San Gabriel Valley Water Co.	Plant 1 & Well 1E	EL MONTE	CAG994001	4B196000476	8011	3	4/10/02	4th Q	97-045	IMISCEL
San Gabriel Valley Water Co.	Plant B7 -Well B7E	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG994001	4B196000264	7703	3	4/10/02	4th Q	97-045	DMISCEL
San Gabriel Valley Water Co.	Plant No. 8 Well 8F	EL MONTE	CAG994001	4B196000445	7955	3	4/10/02	4th Q	97-045	DMISCEL
San Gabriel Valley Water Co.	Plant W1 & Well W1C & W1E	WHITTIER	CAG994001	4B196000475	8010	3	4/10/02	4th Q	97-045	IMISCEL
San Gabriel Valley Water Co.	SGVWC Plant B5	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG994001	4B196000331	7826	3	4/10/02	4th Q	97-045	DMISCEL
San Gabriel Valley Water Co.	San Gabriel Valley Water W6	WHITTIER	CAG994001	4B196000382	7849	3	4/10/02	4th Q	97-045	IMISCEL
San Gabriel Valley Water Co.	San Gabriel Valley Water Co	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG994001	4B196000248	7657	3	4/10/02	4th Q	97-045	DMISCEL
South Montebello Irrigation	Gw-Water Well # 6	MONTEBELLO	CAG994001	4B196000319	7803	3	4/10/02	4th Q	97-045	DMISCEL
South Montebello Irrigation	Gw-Water Well #7	MONTEBELLO	CAG994001	4B196000321	7808	3	4/10/02	4th Q	97-045	DMISCEL
Southern California Edison	Alamitos Generating Station	LONG BEACH	CAG674001	4B196300100	8007	3	4/10/02	3rd Q	97-047	DMISCEL
Southern California Edison	EPTC Pipeline (San Gabriel Ri)		CAG674001	4B196300104	8079	3	4/10/02	3rd Q	97-047	IMISCEL

R0026736

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2005/2006 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Southern California Edison	EPTC Pipeline (San Gabriel Ri)		CAG994002	4B196100040	8125	3	4/10/02	3rd Q	97-043	DMISCEL
Southern California Water Co.	Central District	SANTA FE SPRINGS	CAG994001	4B196000383	7850	3	4/10/02	4th Q	97-045	DMISCEL
Southern California Water Co.	Harrison Well #2	CLAREMONT	CAG994001	4B196000318	7802	3	4/10/02	4th Q	97-045	DMISCEL
Southern California Water Co.	Centralia Site	HAWAIIAN GARDENS	CAG994002	4B196100046	8135	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Hawaiian Site	HAWAIIAN GARDENS	CAG994002	4B196100047	8136	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Imperial Site	NORWALK	CAG994002	4B196100053	8144	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Juan Site	HAWAIIAN GARDENS	CAG994002	4B196100048	8139	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	Vine Site	ARTESIA	CAG994002	4B196100051	8142	3	4/10/02	3rd Q	97-043	IMISCEL
Southern California Water Co.	DACE Plant	NORWALK	CAG994003	4B196400055	8063	3	5/10/03	4th Q	98-055	IMISCEL
Southern California Water Co.	Encinita WTP	TEMPLE CITY (RUDELL)	CAG994003	4B196400057	8065	3	5/10/03	4th Q	98-055	IMISCEL
Spyglass Homeowners Associatio	Gw-Sptglass Homeowners Assoc.	WHITTIER	CAG994001	4B196000188	7555	3	4/10/02	4th Q	97-045	DMISCEL
Suburban Water Systems	La Mirada Plant	LA MIRADA	CAG994001	4B196000278	7717	3	4/10/02	4th Q	97-045	DMISCEL
Suburban Water Systems	Plant 139, Well #2,4,5,6	WEST COVINA	CAG994001	4B196000215	7607	3	4/10/02	4th Q	97-045	DMISCEL
Suburban Water Systems	Plant 140	LOS ANGELES	CAG994001	4B196000133	7368	3	4/10/02	4th Q	97-045	DMISCEL
Suburban Water Systems	Plant 147, Well 3	LA PUENTE	CAG994001	4B196000494	8047	3	4/10/02	4th Q	97-045	IMISCEL
Suburban Water Systems	Plant 409, Well # 2	LA MIRADA	CAG994001	4B196000152	7446	3	4/10/02	4th Q	97-045	DMISCEL
The Boeing Company	C1 (Long Beach) Facility	LONG BEACH	CAG994003	4B196400063	6116	3	5/10/03	4th Q	98-055	DSTORMS
TRW Inc.	Monadnock Facility	CITY OF INDUSTRY (CORPORATE NAME INDUSTRY)	CAG994001	4B196000343	7531	3	4/10/02	4th Q	97-045	DMISCEL
World Oil Marketing Co.	World Oil Station # 61	CERRITOS (DAIRY VALLEY)	CAG834001	4B196600063	7494	2	4/10/02	3rd Q	97-046	HCNWTRS
Xerox Corporation	VOC-Xerox Pomona Facility	POMONA	CAG914001	4B196800005	6783	2	4/10/02	4th Q	97-044	HCNWTRS

LOS CERRITOS CHANNEL WMA

minors

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
Arco Petroleum Products Co.	Tank Leak-16804 Downey Ave.	PARAMOUNT	CA0059731	4B192208004	6730	3	4/10/96	1st Q	91-048	HCNWTRS
Arco Pipe Line Co.	Hathaway Terminal Tank Farm	SIGNAL HILL	CA0058343	4B192187001	6297	3	2/10/02	1st Q	97-018	DSTORMS
Long Beach Unified School Dist	Millikan High Sch Natatorium	LONG BEACH	CA0056120	4B190120001	1003	3	4/10/02	4th Q	97-055	DFILBRI
Paramount Petroleum Corp.	Paramount Refinery	PARAMOUNT	CA0056065	4B192348001	6038	2	10/10/04	1st Q	99-131	DSTORMS
general permits										
Certified Alloy Products, Inc.	Certified Alloy Products, Inc.	LONG BEACH	CAG994003	4B196400064	6734	3	5/10/03	4th Q	98-055	DSTORMS
Equilon Enterprises LLC	Tank Leak-Signal Hill Bulk Plt	LONG BEACH	CAG834001	4B196600025	7338	2	4/10/02	4th Q	97-046	HCNWTRS

Los Angeles Regional Water Quality Control Board
Permits to be Renewed During FY 2005/2006 (cont'd)

Discharger*	Facility	City	NPDES#	WDID#	CI#	TTWQ	Exp. Date	Renewal Quarter	Order No.	Waste Type
LA Co Dept of Public Works	Alamitos Barrier Project 1,2&3	LONG BEACH	CAG994001	4B196000500	6056	3	4/10/02	4th Q	97-045	DMISCEL
Long Beach Water Dept.	Ocean Bl. Peninsula Sewer Proj	LONG BEACH	CAG994001	4B196000542	8174	3	4/10/02	4th Q	97-045	IMISCEL
Long Beach Water Dept.	S12 Sewer Force & Gravity Main	LONG BEACH	CAG994001	4B196000548	8179	3	4/10/02	4th Q	97-045	IMISCEL
Pinnacle Communities, Inc.	Pinnacle Communities	SEAL BEACH	CAG994001	4B196000513	8098	3	4/10/02	4th Q	97-045	DMISCEL
Southern California Edison	EPTC Pipeline (San Gabriel Ri)		CAG674001	4B196300104	8079	3	4/10/02	4th Q	97-047	IMISCEL
CHANNEL ISLANDS WMA										
major										
Avalon, City Of	Avalon WWTP, NPDES	AVALON	CA0054372	4B190100001	0066	1	7/10/99	2nd Q	94-069	DDOMEST
minors										
Southern California Edison	Pebbly Beach Desalination Plt	AVALON	CA0061191	4B192111010	6899	2	11/10/94	1st Q	89-117	DFILBRI
US Navy Naval Air Weapons Stat	San Nicholas Island Desalinatl	SAN NICHOLAS ISLAND	CA0061794	4A560703007	6971	3	7/10/05	3rd Q	00-074	DFILBRI
US Navy Region Southwest	NALF, San Clemente Island WWTP	SAN CLEMENTE ISLAND	CA0110175	4B190703003	6432	1	5/7/10	2nd Q	00-090	DDOMEST
University Of Southern Calif.	Wrigley Institute For Environ.	TWO HARBORS	CA0056651	4B191035002	6068	3	1/10/01	3rd Q	96-006	DMISCEL

***General permit dischargers will be reviewed and may not be "renewed" but allowed to continue with enrollment**

San Gabriel River Watershed

CAG674001	4	DCNWTRS	3
CAG834001	1	DCONTAC	3
CAG914001	10	DDOMIND	5
CAG994001	35	DMISCEL	41
CAG994002	7	DNONCON	2
CAG994003	8	DPROCES	3
		DSTORMS	11
		DWSHWTR	1
		HCNWTRS	10
		IMISCEL	17

Los Cerritos Channel WMA

CAG994003	1	HCNWTRS	2
CAG834001	1	DSTORMS	3
CAG994001	4	DFILBRI	1
CAG674001	1	DMISCEL	2
		IMISCEL	3

Channel Islands WMA

DDOMEST	2
DFILBRI	2
DMISCEL	1

R0026738

Waste Types Categories (prior to treatment or disposal)
DCNWTRS – nonhazardous contaminated groundwater
DNONCON – nonhazardous noncontact cooling water
DPROCES – nonhazardous process waste (produced as part of industrial/manufacturing process)
DSTORMS – nonhazardous stormwater runoff
HCNWTRS – hazardous contaminated groundwater
DFILBRI – nonhazardous filter backwash brine waters
DDOMIND – nonhazardous domestic sewage & industrial waste
DWSHWTR – nonhazardous washwater waste (photo reuse washwater, vegetable washwater)
IMISCEL – inert wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage
DMISCEL – nonhazardous wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage
HCNWTRS – hazardous contaminated groundwater
DCONTAC – nonhazardous contact cooling water
DDOMEST – nonhazardous domestic sewage
NMISCEL – nonhazardous wastes from dewatering, rec. lake overflow, swimming pool wastes, water ride wastewater, or groundwater seepage
ICNWTRS – inert contaminated groundwater

Hazardous – influent or solid wastes that contain toxic, corrosive, ignitable, or reactive substances (prior to treatment or disposal) managed according to applicable Department of Health Services standards
Designated – influent or solid wastes that contain nonhazardous wastes (prior to treatment or disposal) that pose a significant threat to water quality because of their high concentrations
Inert – influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality
Nonhazardous – influent or solid wastes that do not contain soluble pollutants or organic wastes (prior to treatment or disposal) and have little adverse impact on water quality

R0026739

Appendix 4.2 NPDES Storm Water Wastewater Permit Reissuance

There are three Municipal Storm Water Permits in Region 4:

The Ventura County Municipal Storm Water Permit is scheduled for renewal in 2005.

The Los Angeles County Municipal Storm Water Permit is scheduled for renewal in 2002.

The City of Long Beach Municipal Storm Water Permit is scheduled for renewal in 2004.

Appendix 4.3 NPDES Pretreatment Wastewater Permit Reissuance

R0026742

The following are the Pretreatment Programs in Region 4 and their schedule for audit. The pretreatment compliance inspections are scheduled annually in years than an audit is not performed:

PROGRAM	AUDIT
Burbank	2002
Camarillo SD	2003
Las Virgenes MWD	2002
Los Angeles CSD	2004
City of Los Angeles	2004
Ojai Valley SD	2002
Oxnard	2001
San Buenaventura	2005
Simi Valley CSD	2001
Thousand Oaks	2001
Moorpark WTP	2005
Santa Paula	2001

Appendix 4.4 NPDES Compliance

All major NPDES dischargers will be inspected at least once per year. All minors will be inspected at least once during the life of the permit.

Appendix 4.5 Chapter 15 Permit Reissuance

Landfill Waste Discharge Requirements
Status and Proposed Reissuance for Priority Watersheds

Groundwater programs (including landfills) have not been officially integrated into the watershed approach. We expect to integrate these programs increasingly over the next several years. In the meantime, to the extent practicable, landfill issues will be considered when completing "State of the Watershed Reports" and designing watershed monitoring programs.

Our current priority (for the next two years) are the Santa Clara River Watershed, Calleguas Creek Watershed, and Dominguez Channel WMA. We are providing the current status and projected revision dates for landfills in these watersheds:

<u>Santa Clara River Watershed</u>

Wayside Landfill	Current WDR: Adopted in 1975 Landfill is closed WDR will be revised in 2001 to reflect closure/postclosure requirements
Chiquita Canyon Landfill	Current WDR: Adopted in 1998
Bailard Coastal Landfills	Current WDR: Adopted in 1988 Landfill is closed WDR will be rescinded in 2000
Bailard Landfill	Current WDR: Adopted in 1993* Landfill is closed WDR was updated in 2000
Coastal Landfill	Current WDR: Adopted in 1988 Landfill is closed WDR was updated in 2000
Santa Clara Disposal Site	Current WDR: Adopted in 1983* Landfill is closed WDR was updated in 2000
Toland Road Disposal Site	Current WDR: Adopted in 1996

<u>Calleguas Creek Watershed</u>

Simi Valley Landfill	Current WDR: Adopted in 1990 WDR will be updated in 2000

<u>Dominguez Channel WMA</u>

City of Los Angeles, Gaffey St Site	Current WDR: Adopted in 1955 Landfill is closed WDR will be rescinded in 2002

* Indicates that WDRs were revised in 1993 to reflect 40 CFR, Part 258 (Subtitle D) requirements)

R0026747

Appendix 4.6 Non-Chapter 15 Waste Discharge Requirements (WDRs)

Non-Chapter 15 Waste Discharge Requirements (WDRs)
DRAFT Review and Update Strategy
Los Angeles Region
FY 2001/2002 and 2002/2003

The Groundwater Regulatory Unit Programs (WDRs and landfills) have not yet been officially integrated into the watershed approach. We expect to integrate (stepwise) these programs in the next several years. The workplans for the next two years will focus on reducing the review backlog, and to the extent practicable, reviewing and renewing (if appropriate) permits in the targeted watersheds. These facilities will also be considered when designing watershed monitoring programs.

The following tables list all WDRs in the Santa Clara River and Calleguas Creek Watersheds (targeted watersheds in FY01/02), the Dominguez Channel WMA, (targeted watershed for FY02/03), and all WDRs due for review in FY01/02 and 02/03.

Non-Chapter 15 Active Permits in Santa Clara River and Calleguas Creek Watersheds by Threat to Water Quality (FY01/02)

Discharger	Facility	City	WDID#	Expiration Date	Waste Type
SANTA CLARA RIVER WATERSHED					
threat to water quality 1					
Los Angeles County San Dist	Saugus WWRP, Non-NPDES	SAUGUS	4A190107083	4/27/90	DDOMIND
Los Angeles County San Dist	Valencia WWRP, Non-NPDES	VALENCIA	4A190107084	4/27/90	DDOMIND
San Buenaventura City Of	Ventura WWRP, Non-NPDES	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	4A560107002	4/27/90	DDOMIND
Valencia Co.	Natural River Management Plan	SANTA CLARITA	4A191290001	10/28/14	IMISCEL
threat to water quality 2					
Acton Crescent Bay Development	Tract 52883	ACTON	4A196500020	7/22/06	DDOMEST
Acton Plaza Shopping Center	Shopping Center	ACTON	4A191149001	4/4/03	DDOMEST
Ancika / Kaiser	St-Tract 49684	ACTON	4A196500011	7/22/06	DDOMEST
Aquinas, Thomas College	Santa Paula College	SANTA PAULA	4A561000001	2/28/99	DDOMEST
Crown Valley Community Church	Crown Valley Community Church	ACTON	4A191147001	5/30/02	DDOMEST
Gavina & Sons Inc.	St-T.T. 45695	ACTON	4A196500016	7/22/06	DDOMEST
Gene Lesniar	St-Tract 48391	ACTON	4A196500004	7/22/06	DDOMEST
Golden Valley Muni. Water Dist	Gorman WWTP, Non-NPDES	GORMAN	4A190107001	8/19/04	DDOMIND
Hale & Associates	St-22284/Todd Landis	ACTON	4A196500015	7/22/06	DDOMEST
LA Co Dept of Public Works	Lake Hughes Community WWTP	LAKE HUGHES	4B190134001	3/31/05	DDOMEST
Los Angeles County Health Dept	Acton Rehabilitation Center	ACTON	4A190107024	7/14/05	DDOMEST
Los Angeles County Health Dept	Warm Springs Rehabilition Ctr.	CASTAIC	4A190107005	2/26/04	DDOMEST
Los Angeles County Prob Dept	Mendenhall-Munz Boys Camp WWTP	LAKE HUGHES	4A190107076	9/23/04	DDOMEST
Myron Wolter	St-Tt48818	ACTON	4A196500001	7/22/06	DDOMEST
Nova Development Company	Tract 52882	ACTON	4A196500019	7/22/06	DDOMEST
Paradise Ranch Mobile Home Par	Sewage Disp, Castaic	CASTAIC	4A191030001	3/27/99	DDOMEST
Saticoy Food Corp	Vegetable Proc, Santa Paula	SATICOY	4A562408001	9/14/10	DWSHWTR
Sierra View Center	Commercial Development	ACTON	4A191148001	10/17/02	DDOMEST
Tower Investment	St-Tract 50385	AGUA DULCE	4A196500013	7/22/06	DDOMEST
Ventura Co Water Works Dist.	Piru WWTP, Non-NPDES	FILLMORE	4A560114006	9/16/09	DDOMEST
Ventura Co Water Works Dist.	Todd Road Jail Facility	SANTA PAULA	4A560121001	8/21/99	DDOMEST
Ventura Regional San District	Fillmore WWTP, Non-NPDES	FILLMORE	4A560101001	4/5/07	DDOMIND
Ventura Regional San District	Saticoy S.D. WWTP, Non-NPDES	SATICOY	4A560109001	7/19/07	DDOMIND
Ventura Regional San District	Montalvo WWTP, Non-NPDES	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	4A560102001	4/5/07	DDOMIND
Weary & Associates	Tract 52637	ACTON	4A196500021	7/22/06	DDOMEST
threat to water quality 3					
Cen Fed Bank	Tract 49240	ACTON	4A561051001	4/18/06	DDOMEST
Crown Valley Bldg. Supply	Crown Valley Bldg. Supply	ACTON	4A561052001	9/5/06	DDOMEST
Equilon Enterprises LLC	Shell Oil Co.	ACTON	4A192108021	5/11/10	DDOMEST
Fm H Partnerships L.P.	E Z Take Out	ACTON	4A191145001	4/18/06	DDOMEST
Foodmaker Inc.	Jack In The Box	ACTON	4A191288001	5/11/10	DDOMEST
Greystone Homes, Inc.	River Street Property	FILLMORE	4A566700013	1/25/08	IMISCEL
H. R. Textron Inc.	Valencia Facility	VALENCIA	4A192332004	6/30/04	NCNWTRS

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Non-Chapter 15 Active Permits in Santa Clara River and Calleguas Creek Watersheds by Threat to Water Quality (FY01/02) (cont'd)

Discharger	Facility	City	WDID#	Expiration Date	Waste Type
Limoneira Co.	Limoneira&Olivelands Sewer Frm	SANTA PAULA	4A565014002	1/21/03	DDOMEST
Los Angeles County Fire Dept	Fire Camp #11, Acton	ACTON	4A190107079	6/10/08	DDOMEST
Los Angeles County Fire Dept	Camp #16 Correction Inmate Fac	PALMDALE	4A190707001	9/27/11	DDOMEST
Pan American Seed Co.	Pan American Seed, Santa Paula	SANTA PAULA	4A565015001	5/18/02	DPROCES
Sierra Height Mobile Home Est.	Mobile Home Estate	CANYON COUNTRY	4A561036001	10/18/05	DDOMEST
Trans Technology Corp.	Non-NPDES	CANYON COUNTRY	4A192528002	2/24/04	DCNWTRS
Watt Enterprises Ltd.	Building A, Santiago Square	ACTON	4A191144001	4/18/06	DDOMEST
CALLEGUAS CREEK WATERSHED					
threat to water quality 1					
Camarillo Sanitary District	Camarillo WWRP, Non-NPDES	CAMARILLO	4A560100002	9/28/90	DDOMIND
Camrosa Water District	Camrosa WWRP, Non-NPDES	CAMARILLO	4A560106001	4/5/07	DDOMEST
Simi Valley, City Of	Simi Valley WWRP, Non-NPDES	SIMI VALLEY	4A560110003	4/27/90	DDOMIND
threat to water quality 2					
Northrop Grumman Corp. Masd	Newbury Park - Non-NPDES	NEWBURY PARK	4A562436002	10/25/01	HCNWTRS
Ventura Co Water Works Dist.	Moorpark WWTP, Non-NPDES	MOORPARK	4A560103002	4/13/10	DDOMIND
threat to water quality 3					
American Premier Underwriters	G & H Technology Inc.	CAMARILLO	4A561059001	9/16/04	DCNWTRS
Crumpler & Kruger Real Estate	Tierra Rejada Golf Club	VENTURA (COUNTY)	4A561060001	1/26/13	DDOMEST
Galley Enterprises	Village Carwash	THOUSAND OAKS	4B191301001	1/26/13	DCNWTRS
Gillibrand, P. W., Company	Sand & Gravel Plant, Tapo Cyn	SIMI VALLEY	4A562402001	6/12/12	DPROCES
Mushrooms Etc.	Mushrooms Etc.	CAMARILLO	4A562430001	9/18/01	DWSHWTR
Rockwell Science Center LLC	Tank Leak-Rockwell Internation	THOUSAND OAKS	4A562074002	1/22/08	HCNWTRS
Thrifty Oil Co.	Tank Leak-Arco SS#9614	THOUSAND OAKS	4A562433001	4/20/04	HCNWTRS
Transit Mixed Concrete Co.	Sand&Gravel,Ponds-Percolation	MOORPARK	4A562022002	3/24/98	DWSHWTR

Non-Chapter 15 Active Permits in the Dominguez Channel WMA, by Threat to Water Quality (FY02/03)

Discharger	Facility	City	WDID#	Exp. Date	Waste Type
DOMINGUEZ CHANNEL WMA					
threat to water quality 1					
Port Of Long Beach	Dredging-Pier T Marine Termina	LONG BEACH	4B190105030	11/2/03	DDREDGS
threat to water quality 2					
GATX Tank Storage Terminals Co	Carson-Closure Of Surface Impo	CARSON	4B192238004	10/28/04	DCNSOIL
Port Of Long Beach	Dredging-L.B.Harbor 5 Yr Maint	LONG BEACH	4B190105026	6/30/02	DDREDGS
Port of Los Angeles	Dredging-Berths 238-239	SAN PEDRO	4B190106098	12/31/98	DDREDGS
Shell Oil Products Co.	Former Shell Wilmington Plant	CARSON	4B192108020	10/28/04	DCNSOIL
Tosco Corp	L.A.Refinery-Wilm. Land Treat	WILMINGTON	4B192131028	12/7/06	DCNSOIL
threat to water quality 3					
Hugo Neu-Proler Co.	Hugo Neu-Proler Co.	TERMINAL ISLAND	4B191298001	3/29/11	HCNSOIL
Lasmo Oil & Gas Inc	Carson Tank Farm	CARSON	4B192516001	1/22/02	DCNWTRS
Mobil Oil Corp	Mobil Oil Corp.	TORRANCE	4B192079025	1/26/13	DCNSOIL
Port Of Long Beach	Dredging-Berths J245-J247	LONG BEACH	4B190105031	6/30/00	DDREDGS
Port Of Long Beach	Dredging-Terminal Island Conta	LONG BEACH	4B190105033	6/30/03	DDREDGS
Port of Los Angeles	Berth 71 Maintenance Dredging	SAN PEDRO	4B190106110	6/30/02	DDREDGS
Port of Los Angeles	Dredging-Berth 144 Wharf Rep.	SAN PEDRO	4B190106103	5/18/13	DDREDGS
Port of Los Angeles	Dredging-Channel Deepening	SAN PEDRO	4B190106109	8/3/13	DDREDGS

Non-Chapter 15 Active Permits in Region 4, by Threat to Water Quality, then Review Date FY01/02

Discharger	Facility	City	WDID#	Exp. Date	Waste Type
threat to water quality 2					
Crown Valley Community Church	Crown Valley Community Church	ACTON	4A191147001	5/30/02	DDOMEST
Northrop Grumman Corp. Masd	Newbury Park - Non-NPDES	NEWBURY PARK	4A562436002	10/25/01	HCNWTRS
Port Of Long Beach	Dredging-L B.Harbor 5 Yr Maint	LONG BEACH	4B190105026	6/30/02	DDREDGS
threat to water quality 3					
Dept Of Parks And Recreation	Topanga State Park	TOPANGA	4B190801002	6/18/02	DDOMEST
Lasmo Oil & Gas Inc.	Carson Tank Farm	CARSON	4B192516001	1/22/02	DCNWTRS
Mushrooms Etc.	Mushrooms Etc.	CAMARILLO	4A562430001	9/18/01	DWSHWTR
Pan American Seed Co.	Pan American Seed, Santa Paula	SANTA PAULA	4A565015001	6/18/02	DPROCES
Pictsweet Mushroom Farms	Pictsweet Mushroom Farms	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	4A562428001	6/18/02	DMISCEL
Port of Los Angeles	Berth 71 Maintenance Dredging	SAN PEDRO	4B190106110	6/30/02	DDREDGS
Rose Hills Memorial Park Asso	Whittier Facility	WHITTIER	4B199010001	6/18/02	DMISCEL

Non-Chapter 15 Active Permits in Region 4, by Threat to Water Quality, then Review Date FY02/03

Discharger	Facility	City	WDID#	Exp. Date	Waste Type
threat to water quality 2					
Acton Plaza Shopping Center	Shopping Center	ACTON	4A191149001	4/4/03	DDOMEST
BKK Corporation	Cogeneration Plant	WEST COVINA	4B190308007	12/5/02	DNCNCON
Chevron U.S.A. Inc.	El Segundo Groundwater Recycle	EL SEGUNDO	4B192113002	8/25/02	DMISCEL
LA Co Dept of Public Works	Debris Basins Maintenance	LOS ANGELES	4B190107103	9/10/02	DDREDGS
Sierra View Center	Commercial Development	ACTON	4A191148001	10/17/02	DDOMEST
threat to water quality 3					
22601 PCH Associates	Retail Shopping Center	MALIBU	4B191171001	8/20/02	DDOMEST
Ferro Cast Company	Ventura Non-NPDES, Wash Water	VENTURA (CORPORATE NAME SAN BUENAVENTURA)	4A562366002	9/24/02	DWSHWTR
Limoneira Co.	Limoneira&Olivelands Sewer Frm	SANTA PAULA	4A565014002	1/21/03	DDOMEST
Long Beach City Of	Dredging-East Beach Area	LONG BEACH	4B190105006	2/18/03	DDREDGS
Long Beach City Of	Dredging-West Beach Area	LONG BEACH	4B190105018	2/18/03	DDREDGS
Port Of Long Beach	Dredging-Terminal Island Conta	LONG BEACH	4B190105033	6/30/03	DDREDGS

Appendix 4.7 303(d) Listings/TMDL Schedules

Table 7A. Summary Schedule for TMDL Development (by watershed)

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Ventura River Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Ventura River Estuary	DDT	DDT	2001/02	2005/06	Further assessment needed
Ventura River Reach 2 (Main St. to Weldon Canyon)	algae	eutroph.	2000/01	2004/05	nitrogen monitoring
Ventura River Reach 1 (estuary to Main St.)	algae				
Ventura River Estuary	algae, eutroph.				
Ventura River Reach 4 (Coyote Creek to Camino Cielo Rd.)	pumping, water diversions	diversions	2001/02	2005/06	
Ventura River Reach 3 (Weldon Canyon to confl. w/ Coyote Cr.)	pumping, water diversions				
Ventura River Reach 2 (Main St. to Weldon Canyon)	Cu, Zn	metals	2001/02	2005/06	further monitoring
Ventura River Reach 2 (Main St. to Weldon Canyon)	Ag				
Ventura River Reach 1 (estuary to Main St.)	Cu, Zn				
Ventura River Reach 1 (estuary to Main St.)	Ag				
Ventura River Estuary	trash	trash	2001/02	2005/06	
Ventura River Reach 2 (Main St. to Weldon Canyon)	Se	selenium	2001/02	2005/06	

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Miscellaneous Ventura Coastal WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Ventura Harbor: Ventura Keys	Coliform	coliform	2001/02	2006/07	
McGrath Lake McGrath Lake	chlordane, DDT, other pesticides sediment	hist. pest. and effects	2001/02	2006/07	
Port Hueneme Harbor	DDT, PCBs	hist. organics	2001/02	2006/07	
Port Hueneme Harbor	PAHs	PAHs	2001/02	2006/07	
McGrath Beach McGrath Beach Mandalay Beach	Coliform beach closures beach closures	coliform and its effects	2000/01	2001/02	
Port Hueneme Harbor	Zn	zinc	2002/03	2004/05	
Channel Islands Harbor	Pb, Zn	metals	2006/07	2010/11	
Port Hueneme Harbor	TBT	TBT	2006/07	2010/11	Further assessment needed TBT levels have likely dropped

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TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Santa Clara River Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Santa Clara River Estuary	ChemA, toxaphene	hist. pest.	2001/02	2006/07	
Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge)	chloride	chloride	1997/98	2001/02	
Santa Clara River Reach 7 (Blue Cut to West Pier Hwy 99)	chloride				
Santa Clara River Reach 3 (Dam to abv Sp. Crk./blw Timber Cyn)	chloride				
Santa Clara River Reach 9 (Bouquet Cyn Rd. to abv Lang Gaging)	coliform	coliform	2001/02	2005/06	
Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge)	coliform				
Santa Clara River Estuary	Coliform				
Santa Clara River Estuary Beach/Surfers Knoll	Coliform				
Wheeler Canyon/Todd Barranca	nitrate + nitrite	nitrogen and its effects	2001/02	2002/03	
Torrey Canyon Creek	nitrate + nitrite				
Brown Barranca/Long Canyon	nitrate + nitrite				
Mint Canyon Creek Reach 1	nitrate + nitrite				
Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge)	NH3, nitrate + nitrite				
Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge)	org. enrichment/l				
Santa Clara River Reach 7 (Blue Cut to West Pier Hwy 99)	NH3, nitrate + nitrite				
Santa Clara River Reach 3 (Dam to abv Sp. Crk./blw Timber Cyn)	NH3				
Elizabeth Lake	Eutroph.	eutroph. and its effects	2002/03	2004/05	
Elizabeth Lake	DO, pH				
Lake Hughes	Eutroph.				
Lake Hughes	fish kills				
Lake Hughes	algae				
Lake Hughes	odors				
Munz Lake	Eutroph.				
Elizabeth Lake	trash	trash	2004/05	2004/05	
Munz Lake	trash				
Lake Hughes	trash				

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Calleguas Creek Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Fox Barranca	nitrate + nitrite	Nitrogen and its effects	1997/98	2001/02	
Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca)	NH3				
Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca)	nitrate + nitrite				
Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23))	NH3				
Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23))	nitrate + nitrite				
Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn)	NH3				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.)	NH3				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.)	nitrogen				
Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.)	NH3				
Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.)	nitrogen				
Calleguas Creek Reach 3 (Potrero to Somis Rd.)	nitrate + nitrite				
Conejo Creek/Arroyo Conejo N. Fork	NH3				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	NH3				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	algae				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	low DO/org. enrichment				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	NH3				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	algae				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	low DO/org. enrichment				
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	NH3				
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	algae				
Conejo Creek Reach 4 (above Lynn Rd.)	NH3				
Conejo Creek Reach 4 (above Lynn Rd.)	algae				
Conejo Creek Reach 4 (above Lynn Rd.)	Low DO/org. enrichment				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	nitrogen				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	algae				
Beardsley Channel (above Central Ave.)	nitrogen				
Beardsley Channel (above Central Ave.)	algae				
Mugu Lagoon	nitrogen				
Duck pond agric. drain/Mugu Drain/Oxnard Drain	nitrogen				

R0026760

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Calleguas Creek Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	toxicity	water-soluble pest. and effects	1997/98	2003/04	
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	toxicity				
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	toxicity				
Conejo Creek Reach 4 (above Lynn Rd.)	toxicity				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.)	toxicity				
Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.)	toxicity				
Duck pond agric. drain/Mugu Drain/Oxnard Drain	toxicity				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	toxicity				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	chlorpyrifos				
Beardsley Channel (above Central Ave.)	toxicity				
Beardsley Channel (above Central Ave.)	chlorpyrifos				
Fox Barranca	Boron, sulfate, TDS	salts	1997/98	2003/04	
Tapo Canyon Reach 1	Boron, chloride, sulfate, TDS				
Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn)	Boron, chloride, sulfate, TDS			(2000/01 for chlorides)	
Arroyo Simi Reach 2 (above Brea Canyon)	Boron, sulfate, TDS				
Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23))	chloride, sulfate, TDS				
Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca)	chloride, sulfate, TDS				
Calleguas Creek Reach 3 (Potrero to Somis Rd.)	chloride, TDS				
Conejo Creek/Arroyo Conejo N. Fork	sulfate, TDS				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	sulfate, TDS				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	chloride, sulfate. TDS				
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	sulfate, TDS				
Conejo Creek Reach 4 (above Lynn Rd.)	chloride, sulfate, TDS				

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Calleguas Creek Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Arroyo Las Posas Reach 1 (Lewis/Somis Rd. to Fox Barranca)	DDT	historic pest. and effects	1997/98	2004/05	
Arroyo Las Posas Reach 2 (Fox Barranca to Moorpark Fwy (23))	DDT	and vehicle of transport			
Conejo Creek/Arroyo Conejo N. Fork	chlordane, DDT				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	ChemA, dacthal, DDT, endosulfan, toxaphene				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	ChemA, dacthal, DDT, endosulfan, toxaphene				
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	ChemA, dacthal, DDT, endosulfan, toxaphene				
Conejo Creek Reach 4 (above Lynn Rd.)	ChemA, dacthal, DDT, endosulfan, toxaphene				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S. of Broome Rd.)	sediment toxicity				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.)	ChemA, chlordane, DDT, endosulfan, toxaphene				
Calleguas Creek Reach 2(0.5 mi. S. of Broome Rd. to Potrero Rd.)	sediment toxicity				
Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.)	ChemA, chlordane, dacthal, DDT, endosulfan, toxaphene				
Duck pond agric. drain/Mugu Drain/Oxnard Drain #2	ChemA, DDT, chlordane, toxaphene				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	ChemA, chlordane, dacthal, DDT, dieldrin, endosulfan, toxaphene				
Beardsley Channel (above Central Ave.)	ChemA, chlordane, dacthal, DDT, dieldrin, endosulfan, toxaphene				
Mugu Lagoon	siltation				

R0026762

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Calleguas Creek Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date – FY (start of Monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Mugu Lagoon	Sediment toxicity	historic pest. and effects and vehicle of transport (cont'd)			
Duck pond agric. drain/Mugu Drain/Oxnard Drain #2	sediment toxicity				
Mugu Lagoon	Chlordane, dacthal, DDT, endosulfan, toxaphene				
Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn)	Cr, Ni, Ag, Zn	metals	2002/03	2005/06	
Conejo Creek Reach 3 (Tho. Oaks city limit to Lynn Rd.)	Cd, Cr, Ni, Ag				
Conejo Creek Reach 2 (Santa Rosa Rd. to Tho. Oaks city limit)	Cd, Cr, Ni, Ag				
Conejo Creek Reach 1 (confl. Calleguas to Santa Rosa Rd)	Cd, Cr, Ni, Ag				
Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.)	PCBs	PCBs	2001/02	2004/05	
Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.)	PCBs				
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	PCBs				
Beardsley Channel (above Central Ave.)	PCBs				
Mugu Lagoon	PCBs				
Rio de Santa Clara/Oxnard Drain #3	PCBs	sed.-bound organics And effects	2005/06	2008/09	
Rio de Santa Clara/Oxnard Drain #3	ChemA, chlordane, DDT, toxaphene				
Rio de Santa Clara/Oxnard Drain #3	sediment toxicity				
Mugu Lagoon	Hg	mercury	2005/06	2008/09	
Mugu Lagoon	Cu, Ni, Zn	other metals	2005/06	2008/09	
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	trash	trash	2005/06	2008/09	
Beardsley Channel (above Central Ave.)	trash				
Rio de Santa Clara/Oxnard Drain #3	nitrogen	nitrogen	2005/06	2008/09	
Arroyo Simi Reach 1 (Moorpark Fwy (23) to Brea Cyn)	Se	selenium	2005/06	2008/09	
Revolon Slough Main Branch (Mugu Lagoon to Central Ave.)	Se				

R0026763

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT

Assumes these activities are funded to adhere to this schedule

Dominguez Channel and Los Angeles/Long Beach Harbor WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Dominguez Channel Estuary (to Vermont)	benthic comm. effects	PCBs, DDT, other hist. Pest. and their effects	2004/05	2007/08	
Dominguez Channel Estuary (to Vermont)	ChemA, chlordane, DDT, PCBs				
Dominguez Channel Estuary (to Vermont)	aldrin, dieldrin				
Dominguez Channel (above Vermont)	ChemA, chlordane, DDT, PCBs				
Dominguez Channel (above Vermont)	aldrin, dieldrin				
Los Angeles Harbor: Consolidated Slip	benthic comm. effects				
Los Angeles Harbor: Consolidated Slip	DDT, PCBs				
Los Angeles Harbor: Consolidated Slip	chlordane				
Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater)	DDT, PCBs				
Los Angeles Harbor: Southwest Slip	DDT, PCBs				
Los Angeles Harbor: Southwest Slip	sediment toxicity				
San Pedro Bay nearshore and offshore zone: Cabrillo Pier area	DDT, PCBs				
San Pedro Bay nearshore and offshore zone: Cabrillo Pier area	sediment toxicity				
Cabrillo Beach (Inner)	DDT, PCBs				
Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater	benthic comm. effects				
Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater	DDT, PCBs				
Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater	sediment toxicity				
Machado Lake (Harbor Lake)	ChemA, chlordane, DDT, PCBs				
Dominguez Channel (above Vermont)	PAHs	PAHs	2004/05	2007/08	
Dominguez Channel Estuary (to Vermont)	PAHs				
Los Angeles Harbor: Consolidated Slip	PAHs				
Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater)	PAHs				
Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater	PAHs				
San Pedro Bay nearshore and offshore zone: Cabrillo Pier area	PAHs				
Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater)	beach closure	Effects of coliform	2000/01	2001/02	Further Assessment Needed
Cabrillo Beach (Inner)	beach closures				

R0026764

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Dominguez Channel and Los Angeles/Long Beach Harbor WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Torrance Carson Channel	Cu, Pb	Metals	2003/04	2006/07	
Wilmington Drain	Cu, Pb				
Dominguez Channel (above Vermont)	Cu, Pb				
Dominguez Channel (above Vermont)	Cr				
Dominguez Channel (above Vermont)	Zn				
Dominguez Channel Estuary (to Vermont)	Cu, Pb				
Dominguez Channel Estuary (to Vermont)	Cr				
Dominguez Channel Estuary (to Vermont)	Zn				
Los Angeles Harbor: Consolidated Slip	Pb				
Los Angeles Harbor: Consolidated Slip	Cr, Zn				
Machado Lake (Harbor Lake)	algae, eutroph.	nitrogen and its effects	2006/07	2010/11	
Machado Lake (Harbor Lake)	NH3				
Machado Lake (Harbor Lake)	odors				
Wilmington Drain	NH3	ammonia	2005/06	2007/08	
Dominguez Channel (above Vermont)	NH3				
Dominguez Channel Estuary (to Vermont)	NH3				
San Pedro Bay nearshore and offshore zone: Cabrillo Pier area	Zn, Cu, Cr	metals	2006/07	2010/11	
Los Angeles Harbor: Consolidated Slip	TBT	TBT	2006/07	2010/11	Further assessment
Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater)	TBT				
Dominguez Channel (above Vermont)	coliform	coliform	2000/01	2001/02	
Dominguez Channel Estuary (to Vermont)	coliform				
Torrance Carson Channel	coliform				
Wilmington Drain	coliform				
Machado Lake (Harbor Lake)	trash	trash	2006/07	2007/08	

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Santa Monica Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Marina del Rey Harbor Beach	beach closures	coliform and its effect	1998/99	2002/03	
Marina del Rey Harbor Beach	coliform				
Marine del Rey Harbor - Back Basins	coliform				
Medea Creek Reach 2 (abv. confl. with Lindero)	coliform	coliform and its effect	1998/99	2001/02	
Medea Creek Reach 1 (lake to confl. with Lindero)	coliform				
Las Virgenes Creek	coliform				
Malibu Lagoon	swimming restrictions				
Malibu Lagoon	shellfish harvesting ad.				
Malibu Creek: lagoon to Malibu Lake	coliform				
Stokes Creek	Coliform				
Lindero Creek Reach 1	coliform				
Lindero Creek Reach 2 (above lake)	coliform				
Palo Comado	Coliform				
Malibu Beach	beach closures	coliform and its effect	1998/99	2001/02	
Malibu Lagoon Beach (Surfrider)	coliform				
Dockweiler Beach	beach closures				
Dockweiler Beach	coliform				
Redondo Beach	beach closures				
Redondo Beach	coliform				
Santa Monica Beach	beach closures				
Santa Monica Beach	coliform				
Paradise Cove Beach	beach closures				
Paradise Cove Beach	coliform				
Topanga Beach	beach closures				
Topanga Beach	coliform				
Las Flores Beach	coliform				
Torrance Beach	beach closures				
Torrance Beach	coliform				
Trancas Beach (Broad Beach)	beach closures				
Trancas Beach (Broad Beach)	coliform				
Will Rogers Beach	beach closures				
Will Rogers Beach	coliform				
Big Rock Beach	coliform				
Cabrillo Beach (Outer)	beach closures				
Cabrillo Beach (Outer)	coliform				
Venice Beach	beach closures				
Venice Beach	coliform				
Dan Blocker Memorial Beach	coliform				
Leo Carillo Beach (south of County line)	Beach closures				
Leo Carillo Beach (south of County line)	coliform				
Long Point Beach	coliform				
Big Rock Beach	beach closures				

R0026766

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT

Assumes these activities are funded to adhere to this schedule

Santa Monica Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Whites Point Beach	beach closures	coliform and its effect (cont'd)			
Point Dume Beach	beach closures				
Las Tunas Beach	beach closures				
Point Vicente Beach	beach closures				
Malaga Cove Beach	beach closures				
Lunada Bay Beach	beach closures				
Zuma (Westward Beach)	beach closures				
Point Fermin Park Beach	beach closures				
Puerco Beach	beach closures				
Portugese Bend Beach	beach closures				
Royal Palms Beach	beach closures				
Sea Level Beach	beach closures				
Rocky Point Beach	beach closures				
Resort Point Beach	beach closures				
Robert H. Meyer Memorial Beach	beach closures				
Abalone Cove Beach	beach closures				
Flat Rock Point Beach Area	beach closures				
Escondido Beach	beach closures				
Carbon Beach	beach closures				
Castlerock Beach	beach closures				
La Costa Beach	beach closures				
Bluff Cove Beach	beach closures				
Inspiration Point Beach	beach closures				
Nicholas Canyon Beach	beach closures				
Palos Verdes Shoreline Point Beach	Beach closures				
Santa Monica Canyon	pathogens				
Ashland Avenue Drain	coliform				
Sepulveda Canyon	coliform				
Ballona Creek Estuary	coliform				
Ballona Creek Estuary	coliform	coliform and its effect	1998/99	2002/03	
	shellfish harvesting adv.				

R0026767

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Santa Monica Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Malibu Lagoon	eutroph.	nutrients and their effect	1998/99	2001/02	
Malibu Creek: Lagoon to Malibu Lake	nutrients (algae)				
Malibu Creek: lagoon to Malibu Lake	unnatural scum/foam				
Las Virgenes Creek	nutrients (algae)				
Las Virgenes Creek	unnatural scum/foam				
Las Virgenes Creek	low DO, org. enrichment				
Lindero Creek Reach 2 (above lake)	unnatural scum/foam				
Lindero Creek Reach 2 (above lake)	algae				
Lindero Creek Reach 1	unnatural scum/foam				
Lindero Creek Reach 1	algae				
Medea Creek Reach 2 (abv. confl. with Lindero)	algae				
Medea Creek Reach 1 (lake to confl. with Lindero)	algae				
Malibou Lake	algae, eutroph.				
Malibou Lake	low DO, org. enrichment				
Lake Lindero	eutroph., algae				
Lake Lindero	odors				
Westlake Lake	NH3				
Westlake Lake	eutroph., algae				
Westlake Lake	low DO, org. enrichment				
Lake Sherwood	NH3				
Lake Sherwood	Eutroph., algae				
Lake Sherwood	low DO, org. enrichment				
Lake Calabasas	NH3				
Lake Calabasas	Eutroph.				
Lake Calabasas	Low DO, org. enrichment				
Lake Calabasas	pH				
Ballona Wetland	trash	trash	1998/99	2000/01	
Ballona Creek	trash				
Santa Monica Bay Nearshore and Offshore Zone	Hg	metals	2000/01	2003/04	
Santa Monica Bay Nearshore and Offshore Zone	Cd, Cu, Pb, Ni, Ag, Zn				
Santa Monica Bay Nearshore and Offshore Zone	chlordane	chlordane	2004/05	2005/06	
Santa Monica Bay Nearshore amd Offshore Zone	DDT, PCBs	pest. and hist. PCBs, and effects	2005/06	2009/10	
Santa Monica Bay Nearshore and Offshore Zone	sediment toxicity				
Santa Monica Bay Nearshore and Offshore Zone	fish consumption advisory				
Nicholas Canyon Beach	DDT, PCBs				
Paradise Cove Beach	DDT, PCBs				
Robert H. Meyer Memorial Beach	DDT, PCBs				
Point Dume Beach	DDT, PCBs				
Sea Level Beach	DDT, PCBs				

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Santa Monica Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Whites Point Beach	DDT, PCBs	hist. PCBs, pest. and Effects (cont'd)			
Trancas Beach (Broad Beach)	DDT, PCBs				
Topanga Beach	DDT, PCBs				
Royal Palms Beach	DDT, PCBs				
Point Fermin Park Beach	DDT, PCBs				
Redondo Beach	DDT, PCBs				
Puerco Beach	DDT, PCBs				
Portugese Bend Beach	DDT, PCBs				
Amarillo Beach	DDT, PCBs				
Zuma (Westward Beach)	DDT, PCBs				
Malibu Lagoon Beach (Surfrider)	DDT, PCBs				
La Costa Beach	DDT, PCBs				
Big Rock Beach	DDT, PCBs				
Bluff Cove Beach	DDT, PCBs				
Cabrillo Beach (Outer)	DDT, PCBs				
Carbon Beach	DDT, PCBs				
Castlerock Beach	DDT, PCBs				
Escondido Beach	DDT, PCBs				
Flat Rock Point Beach Area	DDT, PCBs				
Inspiration Point Beach	DDT, PCBs				
Las Tunas Beach	DDT, PCBs				
Abalone Cove Beach	DDT, PCBs				
Malaga Cove Beach	DDT, PCBs				
Las Flores Beach	DDT, PCBs				
Long Point Beach	DDT, PCBs				
Malibu Beach	DDT				
Palos Verdes Shoreline Point Beach	pesticides				
Marina del Rey Harbor - Back Basins	DDT, PCBs, chlordane	hist. PCBs, pest. and effects	2001/02	2003/04	
Marina del Rey Harbor - Back Basins	dieldrin				
Marina del Rey Harbor - Back Basins	benthic comm. effects				
Marina del Rey Harbor - Back Basins	fish consumption advisory				
Ballona Creek	PCBs, DDT, ChemA, chlordane, dieldrin	hist. PCBs, pest. and effects	2001/02	2004/05	
Ballona Creek	sediment toxicity				
Ballona Creek Estuary	PCBs, DDT, chlordane				
Ballona Creek Estuary	sediment toxicity				
Sepulveda Canyon	NH3	ammonia	2006/07	2009/10	
Pico Kenter Drain	NH3				
Marina del Rey Harbor - Back Basins	Pb	metals	2001/02	2004/05	
Marina del Rey Harbor - Back Basins	Cu, Zn				
Topanga Cyn Creek	Pb	metals and their effects	2004/05	2006/07	
Sepulveda Canyon	Pb				
Pico Kenter Drain	Pb				
Pico Kenter Drain	Cu				
Pico Kenter Drain	toxicity				
Santa Monica Canyon	Pb				

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Santa Monica Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Ballona Creek	Pb, Ag	metals and their effects	2000/01	2003/04	
Ballona Creek	As, Cu, Cd				
Ballona Creek	toxicity				
Ballona Creek Estuary	Pb, Zn				
Ballona Wetland	As				
Westlake Lake	chlordane	hist. pest.	2006/07	2009/10	
Malibou Lake	chlordane, PCBs				
Lake Calabasas	DDT				
Ashland Avenue Drain	low DO, org. enrichment	DO	2006/07	2008/09	Drain is diverted during dry weather flow
Medea Creek Reach 2 (abv. confl. with Lindero)	trash	trash	2005/06	2006/07	
Medea Creek Reach 1 (lake to confl. with Lindero)	trash				
Lake Lindero	trash				
Lindero Creek Reach 2 (above lake)	trash				
Lindero Creek Reach 1	trash				
Malibu Creek: lagoon to Malibu Lake	trash				
Las Virgenes Creek	trash				
Pico Kenter Drain	trash	trash	2008/09	2009/10	
Ballona Wetland	exotic vegetation	unknown	2006/07	2009/10	
Ballona Wetland	habitat alteration, hydromodi-fication, reduced tidal flushing				
Santa Monica Bay Nearshore and Offshore Zone	debris	debris	2006/07	2009/10	
Lake Lindero	chloride, spec. cond.	chloride	2006/07	2009/10	
Westlake Lake	Pb	metals	2005/06	2007/08	
Westlake Lake	Cu				
Malibou Lake	Cu				
Lake Sherwood	Hg				
Lake Calabasas	Zn				
Lake Calabasas	Cu				
Lake Lindero	Se				
Triunfo Cyn Creek Reach 1	Pb, Hg				
Triunfo Cyn Creek Reach 2	Pb, Hg				
Medea Creek Reach 2 (abv. confl. with Lindero)	Se				
Medea Creek Reach 1 (lake to confl. with Lindero)	Se				
Las Virgenes Creek	Se				
Lindero Creek Reach 2 (above lake)	Se				
Lindero Creek Reach 1	Se				
Ashland Avenue Drain	toxicity	N/A	2006/07	2009/10	Cause of toxicity needs to be determined. Drain is diverted during dry weather flow
Ballona Creek	TBT	TBT	2006/07	2009/10	TBT levels have likely dropped since last sampling
Marina del Rey Harbor - Back Basins	TBT				
Malibu Lagoon	benthic comm. effects	N/A	2006/07	2009/10	Cause needs to be determined

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Los Angeles River Watershed

303(d) Listed Waterbody (Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan amendment)	Comments
Sepulveda Channel/Canyon	NH3	nitrogen and related effects	1999/00	2001/02	
Tujunga Wash (d/s Hansen Dam to Los Angeles River)	NH3				
Tujunga Wash (d/s Hansen Dam to Los Angeles River)	scum, odors				
Los Angeles River Reach 5 (within Sepulveda Basin)	NH3				
Los Angeles River Reach 5 (within Sepulveda Basin)	scum, odors				
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	NH3				
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	scum, odors				
Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.)	NH3				
Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.)	odors, scum				
Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	NH3				
Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	odors, scum				
Los Angeles River Reach 1(u/s Carson St. to estuary)	NH3				
Los Angeles River Reach 1(u/s Carson St. to estuary)	pH				
Los Angeles River Reach 1(u/s Carson St. to estuary)	scum				
Burbank Western Channel	NH3				
Burbank Western Channel	Algae				
Verdugo Wash (Reaches 1 & 2)	algae				
Arroyo Seco Rch 1 (d/s Devil's Gate Dam) & Rch 2 (W. Holly Ave. to Devil's Gate)	algae				
Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)	NH3				
Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)	pH				
Rio Hondo Reach 2 (from Whittier Narrows Flood Control Basin to Spreading Grounds)	NH3				
Compton Creek	pH				
Tujunga Wash (d/s Hansen Dam to Los Angeles River)	coliform	coliform	1999/00	2001/02	
Los Angeles River Reach 6 (u/s of Sepulveda Basin)	coliform				
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	coliform				
Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	coliform				
Los Angeles River Reach 1(u/s Carson St. to estuary)	coliform				
Verdugo Wash (Reaches 1 & 2)	Coliform				
Arroyo Seco Rch 1 (d/s Devil's Gate Dam) & Rch 2 (W. Holly Ave. to Devil's Gate)	Coliform				
Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)	coliform				
Rio Hondo Reach 2 (from Whittier Narrows Flood Control Basin to Spreading Grounds)	coliform				
Compton Creek	coliform				

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Los Angeles River Watershed

303(d) Listed Waterbody (Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan amendment)	Comments
Tujunga Wash (d/s Hansen Dam to Los Angeles River)	trash	trash	1999/00	2000/01	
Los Angeles River Reach 5 (within Sepulveda Basin)	trash				
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	trash				
Los Angeles River Reach 3 (Riverside Dr. to Figueroa St.)	trash				
Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	trash				
Los Angeles River Reach 1(u/s Carson St. to estuary)	trash				
Burbank Western Channel	trash				
Verdugo Wash (Reaches 1 & 2)	trash				
Arroyo Seco Reach 1 (d/s Devil's Gate Dam) & Reach 2 (W. Holly Ave. to Devil's Gate)	trash				
Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)	trash				
Tujunga Wash (d/s Hansen Dam to Los Angeles River)	Cu	metals	2000/01	2003/04	
Compton Creek	Cu, Pb				
Burbank Western Channel	Cd				
Los Angeles River Reach 1(u/s Carson St. to estuary)	Pb				
Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	Pb				
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	Pb				
Rio Hondo Reach 1 (Santa Ana Fwy to Los Angeles River)	Cu, Zn				
Monrovia Cyn Creek	Pb				
Aliso Canyon Wash	Se				
Peck Rd Lake	trash	trash	2008/09	2010/11	
Echo Park Lake	trash				
Lincoln Park Lake	trash				
Los Angeles River Reach 5 (within Sepulveda Basin)	chlorpyrifos	pesticide	2007/08	2010/11	
Peck Rd Lake	low DO, org. enrichment	nitrogen and its effects	2007/08	2010/11	
Peck Rd Lake	odors				
Lincoln Park Lake	NH3				
Lincoln Park Lake	Low DO				
Lincoln Park Lake	Eutroph.				
Lincoln Park Lake	odors				
Echo Park Lake	pH				
Echo Park Lake	Eutroph., NH3, algae				
Echo Park Lake	odors				

R0026772

TABLE 7A. SUMMARY SCHEDULE FOR TMDL DEVELOPMENT
Assumes these activities are funded to adhere to this schedule

Los Angeles River Watershed

303(d) Listed Waterbody (Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan amendment)	Comments
Los Angeles River Reach 5 (within Sepulveda Basin)	ChemA	historic pest.	2002/03	2005/06	
Echo Park Lake Peck Rd Lake	PCBs DDT, chlordane	PCBs and historic pest.	2007/08	2010/11	
Peck Rd Lake Lincoln Park Lake Echo Park Lake	Pb Pb Cu, Pb	metals	2007/08	2010/11	
Los Angeles River Reach 5 (within Sepulveda Basin) Los Angeles River Reach 2 (Figueroa St. to u/s Carson St.)	oil oil	oil	2007/08	2010/11	Further assessment needed
Los Angeles River Reach 6 (u/s of Sepulveda Basin)	Volatile organics	VOCs	2007/08	2010/11	

San Gabriel River Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
San Gabriel River Reach 3 (Whittier Narrows to Ramona)	toxicity	nitrogen and its effects	1999/00	2002/03	
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	NH3				
San Gabriel River Reach 1 (Estuary to Firestone)	NH3				
San Gabriel River Reach 1 (Estuary to Firestone)	algae				
San Gabriel River Reach 1 (Estuary to Firestone)	toxicity				
San Jose Creek Reach 2 (Temple to I-10 at White Ave.)	NH3				
San Jose Creek Reach 2 (Temple to I-10 at White Ave.)	algae				
San Jose Creek Reach 1 (SG confluence to Temple St.)	NH3				
San Jose Creek Reach 1 (SG confluence to Temple St.)	algae				
Coyote Creek	NH3				
Coyote Creek	algae				
Coyote Creek	toxicity				
Walnut Creek	toxicity				
Walnut Creek	pH				
San Gabriel River East Fork	trash	trash	1998/99	1999/00	Completed
Legg Lake	trash	trash	2000/01	2008/09	
Puddingstone Reservoir	DDT, PCBs, chlordane	PCBs & pest.	2000/01	2005/06	
El Dorado Lakes	Hg	metals	2000/01	2005/06	
El Dorado Lakes	Cu, Pb				
Puddingstone Reservoir	Hg				
Legg Lake	Cu, Pb				
Santa Fe Dam Park Lake	Pb, Cu				
Coyote Creek	abnormal fish histology	Dependent on cause	2000/01	2005/06	Further Assessment needed - cause of abnormalities unknown
San Gabriel River Reach 1 (Estuary to Firestone)	abnormal fish histology				
San Gabriel River Estuary	abnormal fish histology				
El Dorado Lakes	algae, NH3, eutroph.	nitrogen and its effects	2001/02	2003/04	
El Dorado Lakes	pH				
Crystal Lake	algae, nutrients				
Legg Lake	NH3				
Legg Lake	pH				
Legg Lake	odors				
Puddingstone Reservoir	low DO, org. enrichment				
Santa Fe Dam Park Lake	pH				
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	Pb	metals	2000/01	2004/05	
San Gabriel River Estuary	As				
Coyote Creek	Ag				

R0026774

San Gabriel River Watershed

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
San Jose Creek Reach 1 (SG confluence to Temple St)	coliform	coliform	2000/01	2002/03	
San Jose Creek Reach 2 (Temple to I-10 at White Ave)	coliform				
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	coliform				
San Gabriel River Reach 1 (Estuary to Firestone)	coliform				
Coyote Creek	coliform				

Los Cerritos Channel and Alamitos Bay WMA

303(d) Listed Waterbody(Reach)	Pollutant	Type of TMDL	TMDL Start Date - FY (start of monitoring)	TMDL Completion Date - FY (Basin Plan Amendment)	Comments
Colorado Lagoon Colorado Lagoon Colorado Lagoon	DDT, PCBs, chlordane dieldrin sediment	hist. pest. and effects	2001/02	2004/05	
Colorado Lagoon Colorado Lagoon	PAHs Pb, Zn	runoff - metals & PAHs	2001/02	2004/05	
Los Cerritos Channel Los Cerritos Channel	Zn Cu, Pb	metals	2001/02	2004/05	
Los Cerritos Channel	NH3	ammonia	2001/02	2004/05	
Los Cerritos Channel	coliform	coliform	2001/02	2004/05	

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
Calleguas Creek WMA	Conejo Creek/Arroyo Conejo N. Fork Calleguas Creek Reaches 1, 2 and 3 Duck pond ag drain/Mugu Drain/Oxnard Drain #2 Conejo Creek Reaches 1, 2, 3, and 4 Rio de Santa Clara (tributary to Mugu Lagoon) Arroyo Las Posas Reaches 1 and 2 Revolon Slough and Beardsley Wash Arroyo Simi Reach 1 Fox Barranca Mugu Lagoon	Nitrogen and its effects: nitrate + nitrite nitrogen ammonia algae low DO/org. enrichment	00/01 RB/SH co-leads	01/02 RB/SH co-lead	01/02 RB lead
	Fox Barranca Tapo Canyon Reach 1 Arroyo Simi Reaches 1 and 2 Arroyo Las Posas Reaches 1 and 2 Calleguas Creek Reach 3 Conejo Creek/Arroyo Conejo N Fork Conejo Creek Reaches 1, 2, 3 and 4	Salts: boron sulfate TDS (total dissolved solids) chloride	01/02 for other salts RB lead 00/01 for chlorides	03/04 for other salts RB/SH co-lead 00/01 for chlorides	03/04 for other salts RB lead 00/01 for chlorides
	Revolon Slough and Beardsley Wash Calleguas Creek Reaches 1 and 2 Duck pond ag drain/Mugu Drain/Oxnard Drain #2 Conejo Creek Reaches 1, 2, 3 and 4	Water-soluble pesticides and effects: chlorpyrifos toxicity	01/02 RB lead	02/03 RB/SH co-lead	02/03 RB lead
	Arroyo Las Posas Reaches 1 and 2 Conejo Creek/Arroyo Conejo N. Fork Conejo Creek Reaches 1, 2, 3 and 4 Calleguas Creek Reaches 1 and 2 Duck pond ag drain/Mugu Drain/Oxnard Drain #2 Revolon Slough and Beardsley Wash Mugu Lagoon	Historic pesticides and effects, siltation: DDT dacthal endosulfan ChemA toxaphene dieldrin sediment toxicity	03/04 RB lead	03/04 RB/SH co-lead	04/05 RB lead
	Arroyo Simi Reach 1 Conejo Creek Reach 3 Conejo Creek Reach 2 Conejo Creek Reach 1	Metals: Cr, Ni, Ag, Zn Cd	04/05 RB lead	05/06 RB/SH co-lead	05/06 RB lead

R0026778

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Calleguas Creek Reach 1 (estuary to 0.5 mi. S of Broome Rd.) Calleguas Creek Reach 2 (0.5 mi. S of Broome Rd. to Potrero Rd.) Revolon Slough Main Branch (Mugu Lagoon to Central Ave.) Beardsley Channel (above Central Ave.) Mugu Lagoon	PCBs	03/04	03/04	04/05
Santa Monica Bay WMA - Malibu Creek Watershed	Medea Creek Reaches 1 and 2 Las Virgenes Creek Lindero Creek Reaches 1 and 2 Stokes Creek Palo Comado Malibu Creek: lagoon to Malibu Lake Malibu Lagoon	Coliform and effects: coliform swimming restrictions shellfish harvesting advisory	00/01 RB/SH co-lead	00/01 RB/SH co-lead	01/02 RB lead
	Lake Calabasas Lake Sherwood Westlake Lake Lake Lindero Malibou Lake Lindero Creek Reaches 1 and 2 Medea Creek Reaches 1 and 2 Las Virgenes Creek Malibu Creek: lagoon to Malibu Lake Malibu Lagoon	Nutrients and their effects (Phase I): ammonia pH low dissolved oxygen algae eutrophication organic enrichment unnatural foam/scum nutrients odors	00/01 RB/SH co-lead	01/ 02 RB/SH co-lead	01/02 RB lead
Santa Monica Bay WMA - Marina del Rey Harbor	Marina del Rey Harbor Beach Marina del Rey Harbor - Back Basins	Coliform and its effects: coliform beach closures	01/02 RB/SH co-lead	02/03 RB/SH co-lead	02/03 RB lead

R0026779

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Marina del Rey Harbor - Back Basins	Historic PCBs, pesticides and effects: DDT, PCBs, chlordane PCBs chlordane dieldrin benthic comm. effects fish consumption advisory	03/04 RB/SH co-lead	03/04 RB/SH co-lead	03/ 04 RB lead
	Marina del Rey Harbor - Back Basins	metals: Pb, Cu, Zn	03/04 RB/SH co-lead	03/04 RB/SH co-lead	04/ 05 RB lead
Santa Monica Bay WMA - greater Santa Monica Bay	Greater Santa Monica Bay beaches	coliforms, pathogens, beach closures (Phase I)	00/01 RB/SH co-lead	00/01 RB/SH co-lead	01/ 02 RB lead
	Santa Monica Bay Nearshore and Offshore Zone	Metals: Hg, Cd, Cu, Pb, Ni, Ag, Zn	02/03 RB/SH co-lead	02/03 RB/SH co-lead	03/ 04 RB lead
	Santa Monica Bay Nearshore and Offshore Zone	chlordane	04/05 RB/SH co-lead	05/06 RB/SH co-lead	05/06 RB lead
Santa Monica Bay WMA - Ballona Creek	Ballona Creek Ballona Wetland	trash	99/00 RB/SH co-lead	00/01 RB/SH co-lead	00/01 RB lead
	Ballona Estuary	coliform shellfish harvesting advisory	01/02 RB/SH co-lead	01/02 RB/SH co-lead	02/03 RB lead
	Ballona Creek Ballona Creek Estuary Ballona Wetland	Metals and its effects: Pb, Ag, As, Cu, Cd, Zn toxicity	02/03 RB/SH co-lead	02/03 RB/SH co-lead	03/04 RB lead

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Ballona Creek Ballona Creek Estuary Ballona Creek Estuary	Historic PCBs , Pesticides and effects: PCBs DDT ChemA chlordane dieldrin sediment toxicity	03/04 RB/SH co-lead	03/04 RB/SH co-lead	04/05 RB lead
	Topanga Cyn Creek Sepulveda Canyon Pico Kenter Drain Pico Kenter Drain Pico Kenter Drain Santa Monica Canyon	Metals and its effects: Pb, CU toxicity	05/06	06/07	06/07
Los Angeles River WMA	Los Angeles River Reaches 1, 2, 3, 4, and 5 Burbank Western Channel Verdugo Wash Reaches 1 and 2 Arroyo Seco Reach 1 Rio Hondo Reaches 1 and 2 Compton Creek Sepulveda Channel/Canyon Tujunga Wash (d/s Hansen Dam to LA River)	Nitrogen and related effects: ammonia pH algae scum odors	00/01 RB lead	00/01 RB/SH co-lead	01/02 RB lead
	Los Angeles River Reaches 1, 2, 4, and 6 Tujunga Wash (d/s Hansen Dam to LA River) Verdugo Wash Reaches 1 and 2 Arroyo Seco Reach 1 Rio Hondo Reaches 1 and 2 Compton Creek	Coliform	00/01 RB lead	00/01 RB/SH co-lead	01/ 02 RB lead
	Los Angeles River Reaches 1, 2, 3, 4, and 5 Burbank Western Channel Verdugo Wash Reaches 1 and 2 Arroyo Seco Reach 1 Rio Hondo Reach 1 Tujunga Wash (d/s Hansen Dam to LA River)	Trash	99/00 RB lead	00/01 RB/SH co-lead	00/01 RB lead

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Los Angeles River Reaches 1, 2, and 4 Burbank Western Channel Compton Creek Monrovia Canyon Creek Rio Hondo Reach 1 Tujunga Wash (d/s Hansen Dam to LA River) Aliso Canyon Creek	Metals: copper lead zinc selenium cadmium	02/03 RB lead	02/03 RB/SH co-lead	03/04 RB lead
	Los Angeles River Reach 5 (within Sepulveda Basin)	Historic pesticide: chemA	04/05 RB lead	05/06 RB/SH co-lead	05/06 RB lead
Dominguez Channel WMA	Cabrillo Pier area Cabrillo Beach (inner)	beach closures	01/02 RB/SH co-lead	01/02 RB/SH co-lead	01/02 RB lead
	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) Los Angeles Harbor: Southwest Slip San Pedro Bay nearshore and offshore zone: Cabrillo Pier area Cabrillo Beach (Inner) Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater Machado Lake (Harbor Lake)	Historic pesticides and their effects: ChemA, chlordane, DDT, PCBs aldrin, dieldrin sediment toxicity, benthic comm. effects	06/07	07/08	07/08
	Dominguez Channel Estuary (to Vermont) Dominguez Channel (above Vermont) Los Angeles Harbor: Consolidated Slip Los Angeles Harbor (part. Main Ch., Fish Hbr, Cabrillo Pier, and breakwater) San Pedro Bay nearshore and offshore zone: Cabrillo Pier area Cabrillo Beach (Inner) Long Beach Harbor, part. Main Ch., SE Basin, West Basin, Pier J, and breakwater	PAHs	06/07	07/08	07/08

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Torrance Carson Channel Wilmington Drain Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont) Los Angeles Harbor: Consolidated Slip	Metals: Cu, Pb, Cr, Zn,	05/06	06/07	06/07
	Torrance Carson Channel Wilmington Drain Dominguez Channel (above Vermont) Dominguez Channel Estuary (to Vermont)	Coliform	01/02	01/02	01/02
Ventura Coastal WMA	McGrath Beach Mandalay Beach	Coliform and its effects: coliform beach closures	01/ 02 RB/SH co-lead	01/02 RB/SH co-lead	01/ 02 RB lead
	Ventura Harbor: Ventura Keys	coliform	05/06	06/07	06/07
	McGrath Lake	Historic Pesticides and their effects: Chlordane, DDT, other pesticides Sediment toxicity	05/06	06/07	06/07
	Port Hueneme Harbor	Historic Organics DDT, PCBs	05/06	06/07	06/07
	Port Hueneme Harbor	PAHs	05/06	06/07	06/07
	Port Hueneme Harbor	Zn	03/04	03/ 04	04/05
Ventura River Watershed	Ventura River Estuary	DDT	04/05	05/06	05/06
	Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.) Ventura River Estuary	eutrophication	03/04	03/04	04/05

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
	Ventura River Reach 2 (Main St. to Weldon Canyon) Ventura River Reach 1 (estuary to Main St.)	Metals: Cu, Zn, Ag,	04/05	05/06	05/06
	Ventura River Estuary	Trash	04/05	05/06	05/06
	Ventura River Reach 2 (Main St. to Weldon Canyon)	Se	04/05	05/06	05/06
Santa Clara River WMA	Santa Clara River Reaches 3, 7, and 8	Chloride	00/01 RB/SH co-lead	99/00 RB/SH co-lead	01/02 RB lead
	Santa Clara River Reaches 3, 7, and 8 Mint Canyon Reach 1 Brown Barranca/Long Canyon Torrey Canyon Creek Wheeler Canyon/Todd Barranca	Nitrogen and its effects: nitrate + nitrite ammonia organic enrichment low dissolved oxygen	01/02 RB/SH co-lead	01/02 RB/SH co-lead	02/03 RB lead
	Santa Clara River Estuary	Historic Pesticides: ChemA, toxaphene	05/06	06/07	06/07
	Santa Clara River Reach 9 (Bouquet Cyn Rd. to abv Lang Gaging) Santa Clara River Reach 8 (W Pier Hwy 99 to Bouquet Cyn Rd Bridge) Santa Clara River Estuary Santa Clara River Estuary Beach/Surfers Knoll	Coliform	04/05	05/06	05/06
	Elizabeth Lake Munz Lake Lake Hughes	Eutrophication and its effects: Low DO, fish kills, algae odors	03/04	03/04	04/05
	Elizabeth Lake Munz Lake Lake Hughes	Trash	04/05	04/05	04/05

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
San Gabriel River WMA	San Gabriel River Reaches 1, 2, and 3 San Jose Creek Reaches 1 and 2 Walnut Creek Coyote Creek	Nitrogen and its effects: ammonia toxicity pH algae	01/02 RB/SH co-lead	01/02 RB/SH co-lead	02/03 RB lead
	San Gabriel River East Fork	Trash	99/00 RB/SH co-lead	99/00 RB/SH co-lead	RB adoption on 10/29/99
	San Gabriel River Reach 2 San Gabriel River Estuary Coyote Creek	Metals: Pb As Ag	04/05 RB/SH co-lead	04/05 RB/SH co-lead	04/05 RB lead
	San Gabriel River Reaches 1 and 2 San Jose Creek Reaches 1 and 2 Coyote Creek	coliform	02/03 RB/SH co-lead	02/03 RB/SH co-lead	02/03 RB lead
	Puddingstone Reservoir	PCBs and Pesticides: DDT, chlordane, PCs	04/05	05/06	05/06
	El Dorado Lakes Puddingstone Reservoir Legg Lake Santa Fe Dam Park Lake	Metals: Hg, Cu, Pb	04/05	05/06	05/06
	Coyote Creek San Gabriel River Reach 1 (Estuary to Firestone) San Gabriel River Estuary	abnormal fish histology Cause unknown	04/05	05/06	05/06
	El Dorado Lakes Puddingstone Reservoir Legg Lake Santa Fe Dam Park Lake Crystal Lake	Nitrogen and its effects: Eutrophication, algae, NH3, pH, Nutrients, orders, low DO, enrichment	03/04	03/04	03/04

Table 7B. Detailed Schedule of TMDL Activities (started in the next five years)

Watershed	Waterbody (Reach)	Pollutant	Develop Technical TMDL	Develop Implementation Plan	Basin Plan Amendment
Los Cerritos Channel and Alamitos Bay WMA	Colorado Lagoon	Historic pesticides and effects: DDT, PCBs, Chlordane, Dieldrin Sediment toxicity	03/04	04/05	04/05
	Colorado Lagoon	Metals & PAHs: Zn, Cu, Pb, PAHs	03/04	04/05	04/05
	Los Cerritos Channel	Metals: Zn, Cu, Pb	03/04	04/05	04/05
	Los Cerritos Channel	Ammonia	03/04	04/05	04/05
	Los Cerritos Channel	coliform	03/04	04/05	04/05

R0026786

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Calleguas Creek – Nitrogen and Its Effects
Consent Decree: March 2002

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	99/00	(1/10 py) (st)		Problem statement write-up	6/00
Numeric Target	00/01	(2/5) py)(st)		Rationale for numeric targets	9/00
Source Analysis	00/01	(3/5 py)(st)	$25,000	Write-up of source analysis	11/00
Allocations	00/01	(2/5 py)	$25,000	Numeric allocations and rationale	7/01
Implementation Planning					
Implementation Plan	00/01	(1/5 py)		Report	8/01
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	2/02
Implementation					
Monitoring	01/02	(1/5py)		Monitoring data and QA/QC	2/02
Reevaluation	01/02	(1/5 py)		Report of reevaluation findings	3/02

Calleguas Creek – Salts
Consent Decree: NA

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)		Problems statement write-up	4/01
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	6/01
Source Analysis	01/02	(2/5 py)		Write-up of source analysis	10/01
Allocations	01/02	(3/10 py)	$25,000	Numeric allocations and rationale	3/02
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	3/02
Basin Plan Amendment	02/03	(1/5 py)		Draft Basin Plan Amendment	6/03
Implementation					
Monitoring	02/03	(1/5 py)		Monitoring data and QA/QC	3/03
Reevaluation	02/03	(1/5 py)		Report of reevaluation findings	4/03

Calleguas Creek – Chloride
Consent Decree: 3/01

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	99/00	(1/10 py) (fed)		Problem statement write-up	1/00
Numeric Target	99/00	(2/5py)(fed)		Rationale for numeric target	12/99
Source Analysis	99/00	(2/5py)(fed)		Write-up of source analysis	12/99
Allocations	99/00	(1/5py)(fed)		Numeric allocations and Rationale	2/00
Implementation Planning					
Implementation Plan	99/00	(1/5py)		Report	12/00
Basin Plan Amendment	00/01	(1/10 py)(st)		Draft Basin Plan Amendment	3/01
Implementation					
Monitoring	00/01	(2/5 py)		Monitoring data and QA/QC	7/01
Reevaluation	00/01	(1/5 py)(st)		Report of reevaluation findings	8/01

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Calleguas Creek – Water-Soluble Pesticides and Effects
Consent Decree: March 2005

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	1/02
Numeric Target	01/02	(2/5 py)		Rationale for numeric targets	3/02
Source Analysis	02/03	(2/5 py)	$50,000	Write-up of source analysis	8/02
Allocations	02/03	(3/10 py)	$50,000	Numeric allocations and rationale	5/03
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	6/03
Basin Plan Amendment	03/04	(1/5 py)		Basin Plan Amendment	2/04
Implementation					
Monitoring	05/06	(1/5 py)		Monitoring data and QA/QC	1/06
Reevaluation	06/07	(1/5 py)		Report of reevaluation findings	1/07

Calleguas Creek - Historic Pesticides and Effects
Consent Decree: March 2005

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	1/03
Numeric Target	02/03	(2/5 py)	$25,000	Rationale for numeric targets	3/03
Source Analysis	03/04	(2/5 py)	$25,000	Write-up of source analysis	8/03
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	5/04
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	6/04
Basin Plan Amendment	04/05	(1/5 py)		Basin Plan Amendment	1/05
Implementation					
Monitoring	06/07	(1/5 py)		Monitoring data and QA/QC	1/07
Reevaluation	07/08	(1/5 py)		Report of reevaluation findings	1/08

Calleguas Creek – PCBs
Consent Decree: March 2005

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	1/03
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	3/03
Source Analysis	03/04	(2/5 py)	$25,000	Write-up of source analysis	8/03
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	5/04
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	6/04
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	1/05
Implementation					
Monitoring	06/07	(1/5 py)		Monitoring data and QA/QC	2/07
Reevaluation	07/08	(1/5 py)		Report of reevaluation findings	4/08

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Santa Monica Bay WMA – Malibu Creek – Coliform and Effects
Consent Decree: March 2002

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	98/99	(1/10 py)		Problem statement write-up	5/99
Numeric Target	00/01	(2/5 py)(fed)		Rationale for numeric targets	10/01
Source Analysis	00/01	(2/5 py)(fed)		Write-up of source analysis	1/01
Allocations	00/01	(3/10 py)	$50 K modeling (fed)	Numeric allocations and rationale, Model for coliform and nutrients	4/01
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	4/01
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	8/01
Implementation				Monitoring data and QA/QC	
Monitoring		(1/5 py)		Report of reevaluation findings	3/03
Reevaluation		(1/5 py)		Problem statement write-up	4/05

Santa Monica Bay WMA – Malibu Creek – Nutrients and Effects
Consent Decree: March 2002

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	99/00	(1/10 py)		Problem statement write-up	5/99
Numeric Target	99/00	(2/5 py)(fed)		Rationale for numeric targets	10/01
Source Analysis	00/01	(2/5 py)(fed)		Write-up of source analysis	1/01
Allocations	00/01	(3/10 py)	$50 K modeling (fed)	Model for coliform and nutrients in Malibu Lagoon	4/01
Implementation Planning					
Implementation Plan	00/01	(1/5 py)		Report	4/01
Basin Plan Amendment	00/01	(1/5 py)		Draft Basin Plan Amendment	6/01
Implementation				Monitoring data and QA/QC	
Monitoring		(1/5 py)		Report of reevaluation findings	3/03
Reevaluation		(1/5 py)		Problem statement write-up	4/05

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Table 7C. Detailed TMDL Tasks Schedule (next three years)

Santa Monica Bay WMA – Marina del Rey – Coliform and Effects
Consent Decree: March 2003

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)		Problems statement write-up	1/01
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	3/01
Source Analysis	01/02	(2/5 py)	$20,000	Write-up of source analysis	9/01
Allocations	01/02	(3/10 py)	$30,000	Numeric allocations and rationale	4/02
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	5/02
Basin Plan Amendment	02/03	(1/5 py)		Draft Basin Plan Amendment	12/02
Implementation					
Monitoring	03/04	(1/5 py)		Monitoring data and QA/QC	11/03
Reevaluation	04/05	(1/5 py)		Report of reevaluation findings	12/04

Santa Monica Bay WMA – Marina del Rey –Historic PCBs, Pesticides and Effects
Consent Decree: March 2005

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	1/03
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	3/03
Source Analysis	02/03	(2/5 py)	$50,000	Write-up of source analysis	5/03
Allocations	02/03	(3/10 py)	$50,000	Numeric allocations and rationale	9/03
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	11/03
Basin Plan Amendment	03/04	(1/5 py)		Draft Basin Plan Amendment	06/04
Implementation					
Monitoring	05/06	(1/5 py)		Monitoring data and QA/QC	9/05
Reevaluation	06/07	(1/5 py)		Report of reevaluation findings	11/06

Santa Monica Bay WMA – Marina del Rey –Metals
Consent Decree: March 2005

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	12/02
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	2/03
Source Analysis	03/04	(2/5 py)	$25,000	Write-up of source analysis	7/03
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	4/04
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	5/04
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	12/04
Implementation					
Monitoring	05/06	(1/5 py)		Monitoring data and QA/QC	2/06
Reevaluation	06/07	(1/5 py)		Report of reevaluation findings	4/07

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Santa Monica Bay WMA – Beaches – Coliform and Effects
Consent Decree: March 2002

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	99/00	(1/10 py)		Problems statement write-up	12/99
Numeric Target	99/00	(2/5 py)	$100,000	Rationale for numeric targets	1/00
Source Analysis	00/01	(2/5 py)	$130,000	Write-up of source analysis	7/00
Allocations	00/01	(3/10 py)		Numeric allocations and rationale	11/00
Implementation Planning					
Implementation Plan	00/01	(1/5 py)		Report	5/01
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	11/01
Implementation					
Monitoring	02/03	(1/5 py)		Monitoring data and QA/QC	11/02
Reevaluation	03/04	(1/5 py)		Report of reevaluation findings	12/03

Santa Monica Bay WMA – Nearshore & Offshore – Metals
Consent Decree: March 2004

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	12/01
Numeric Target	01/02	(2/5 py)		Rationale for numeric targets	2/02
Source Analysis	01/02	(2/5 py)	$50,000	Write-up of source analysis	6/02
Allocations	02/03	(3/10 py)	$50,000	Numeric allocations and rationale	10/02
Implementation Planning					
Implementation Plan	02/03	(1/5 py)		Report	2/03
Basin Plan Amendment	03/04	(1/5 py)		Draft Basin Plan Amendment	9/03
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	10/04
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	12/05

Santa Monica Bay WMA – Ballona Creek – Trash
Consent Decree: March 2001

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	98/99	(1/10 py)		Problems statement write-up	4/99
Numeric Target	99/00	(2/5 py)		Rationale for numeric targets	11/99
Source Analysis	99/00	(2/5 py)		Write-up of source analysis	12/99
Allocations	99/00	(3/10 py)		Numeric allocations and rationale	12/99
Implementation Planning					
Basin Plan Amendment	00/01	(1/5 py)		Report	3/01
Implementation					
Monitoring	02/03	(1/5 py)		Monitoring data and QA/QC	3/03
Reevaluation	02/03	(1/5 py)		Report of reevaluation findings	4/03

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Santa Monica Bay WMA – Ballona Creek – Coliform and Effects
Consent Decree: March 2006

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)		Problems statement write-up	7/00
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	9/00
Source Analysis	00/01	(2/5 py)	$20,000	Write-up of source analysis	2/01
Allocations	01/02	(3/10 py)	$20,000	Numeric allocations and rationale	11/01
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	12/01
Basin Plan Amendment	02/03	(1/5 py)		Draft Basin Plan Amendment	7/02
Implementation					
Monitoring	03/04	(1/5 py)		Monitoring data and QA/QC	12/03
Reevaluation	03/04	(1/5 py)		Report of reevaluation findings	3/04

Santa Monica Bay WMA – Ballona Creek –Metals and Effects
Consent Decree: March 2004

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	7/01
Numeric Target	01/02	(2/5 py)		Rationale for numeric targets	9/01
Source Analysis	01/02	(2/5 py)	$25,000	Write-up of source analysis	2/02
Allocations	02/03	(3/10 py)	$25,000	Numeric allocations and rationale	11/02
Implementation Planning					
Implementation Plan	02/03	(1/5 py)		Report	12/02
Basin Plan Amendment	03/04	(1/5 py)		Draft Basin Plan Amendment	7/03
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	4/05
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	5/06

Santa Monica Bay WMA – Ballona Creek – Historic PCBs, Pesticides and Effects
Consent Decree: March 2004

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	7/02
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	9/02
Source Analysis	02/03	(2/5 py)	$25,000	Write-up of source analysis	11/02
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	11/03
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	12/03
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	7/04
Implementation					
Monitoring	05/06	(1/5 py)		Monitoring data and QA/QC	9/06
Reevaluation	06/07	(1/5 py)		Report of reevaluation findings	12/07

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Los Angeles River – Nitrogen and Effects
Consent Decree: March 2003

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/99	(1/10 py)		EPA Development	2/99
Numeric Target	00/99	(2/5 py)		EPA Development	4/99
Source Analysis	99/00	(2/5 py)		EPA Development	8/99
Allocations	99/00	(3/10 py)		EPA Development	02/00
Implementation Planning					
Implementation Plan	00/01	(1/5 py)			01/01
Basin Plan Amendment	01/02	(1/5 py)			08/01
Implementation					
Monitoring	02/03	(1/5 py)			02/03
Reevaluation	03/04	(1/5 py)			04/04

Los Angeles River – Coliform
LA River Coliform

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	99/00	(1/10 py)		EPA Development	4/00
Numeric Target	99/00	(2/5 py)		EPA Development	6/00
Source Analysis	00/01	(2/5 py)		EPA Development	12/00
Allocations	00/01	(3/10 py)		EPA Development	4/01
Implementation Planning					
Implementation Plan	00/01	(1/5 py)			4/01
Basin Plan Amendment	01/02	(1/5 py)			8/01
Implementation					
Monitoring	02/03	(1/5 py)			4/03
Reevaluation	03/04	(1/5 py)			6/04

Los Angeles River – Trash
Consent Decree: March 2001

Task	FY	Staff Resources	Contracts	Product	Completion Date
TMDL Development					
Problem Statement	98/99	(1/10 py)		Problem statement write-up	4/99
Numeric Target	99/00	(2/5 py)		Rationale for numeric targets	11/99
Source Analysis	99/00	(2/5 py)		Write-up of source analysis	12/99
Allocations	99/00	(3/10 py)		Numeric allocations and rationale	12/99
Implementation Planning					
Implementation Plan	00/01	(1/5 py)		Report	1/00
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	1/01
Implementation					
Monitoring	03/04	(1/5 py)		Monitoring data and QA/QC	4/04
Reevaluation	03/04	(1/5 py)		Report of reevaluation findings	5/05

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Los Angeles River – Metals
Consent Decree: March 2004

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	9/01
Numeric Target	01/02	(2/5 py)		Rationale for numeric targets	1/02
Source Analysis	01/02	(2/5 py)	$50,000	Write-up of source analysis	7/02
Allocations	02/03	(3/10 py)	$50,000	Numeric allocations and rationale	11/02
Implementation Planning					
Implementation Plan	02/03	(1/5 py)		Report	11/02
Basin Plan Amendment	02/03	(1/5 py)			7/02
Implementation					
Monitoring	03/04	(1/5 py)		Monitoring data and QA/QC	11/03
Reevaluation	03/04	(1/5 py)		Report of reevaluation findings	12/03

Dominguez Channel WMA - Coliform

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)		Problems statement write-up	7/00
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	7/00
Source Analysis	00/01	(2/5 py)	$20,000	Write-up of source analysis	3/01
Allocations	01/02	(3/10 py)	$20,000	Numeric allocations and rationale	8/01
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	9/01
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	2/02
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	12/04
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	1/06

Ventura Coastal WMA – McGrath Beach – Coliform and Effects

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)(st)		Problem statement write-up	8/00
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	12/00
Source Analysis	00/01	(2/5 py)	$10,000	Write-up of source analysis	5/01
Allocations	01/02	(3/10 py)		Numeric allocations and rationale	11/01
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	11/01
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	6/02
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	11/04
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	12/05

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Ventura Coastal WMA – Port Hueneme – Zinc

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	11/02
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	1/03
Source Analysis	02/03	(2/5 py)	$25,000	Write-up of source analysis	6/03
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	4/04
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	4/04
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	11/04
Implementation					
Monitoring	06/07	(1/5 py)		Monitoring data and QA/QC	12/06
Reevaluation	08/09	(1/5 py)		Report of reevaluation findings	1/08

Ventura River – Eutrophication

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)		Problems statement write-up	11/02
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	1/03
Source Analysis	02/03	(2/5 py)	$50,000	Write-up of source analysis	6/03
Allocations	03/04	(3/10 py)	$50,000	Numeric allocations and rationale	3/04
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	4/04
Monitoring	06/07	(1/5 py)		Monitoring data and QA/QC	8/06
Reevaluation	07/08	(1/5 py)		Report of reevaluation findings	9/07
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	11/04
Implementation					

Santa Clara River WMA - Chloride

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development				Changing Objectives no TMDL	
Problem Statement	98/99	(1/10 py)		Problem statement write-up	4/99
Numeric Target	99/00	(2/5 py)		Rationale for numeric targets	8/99
Source Analysis	99/00	(2/5 py)		Write-up of source analysis	12/99
Allocations		(3/10 py)		Numeric allocations and rationale	N/A
Implementation Planning	99/00				
Implementation Plan		(1/5 py)		Report	12/99
Basin Plan Amendment	01/02	(1/5 py)		Draft Basin Plan Amendment	8/01
Implementation					
Monitoring	02/03	(1/5 py)		Monitoring data and QA/QC	3/03
Reevaluation	02/03	(1/5 py)		Report of reevaluation findings	3/03

Table 7C. Detailed TMDL Tasks Schedule (next three years)

Santa Clara River WMA –Nitrogen and Effects

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)(st)		Problems statement write-up	4/01
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	3/01
Source Analysis	01/02	(2/5 py)	$50,000	Write-up of source analysis	8/01
Allocations	01/02	(3/10 py)	$50,000	Numeric allocations and rationale	5/02
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	6/02
Basin Plan Amendment	02/03	(1/5 py)		Draft Basin Plan Amendment	1/03
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	1/05
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	2/06

San Gabriel River –Nitrogen and Effects

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)(st)		Problems statement write-up	12/00
Numeric Target	00/01	(2/5 py)		Rationale for numeric targets	1/01
Source Analysis	00/01	(2/5 py)	$50,000	Write-up of source analysis	5/01
Allocations	00/01	(3/10 py)	$50,000	Numeric allocations and rationale	3/ 02
Implementation Planning					
Implementation Plan	01/02	(1/5 py)		Report	4/02
Basin Plan Amendment	02/03	(1/5 py)			11/02
Implementation					
Monitoring	03/04	(1/5 py)		Monitoring data and QA/QC	1/04
Reevaluation	04/05	(1/5 py)		Report of reevaluation findings	2/05

San Gabriel River – East Fork – Trash (COMPLETED) Approved by OAL 9/00, approved by USEPA 12/00

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement					
Numeric Target					
Source Analysis					
Allocations					
Implementation Planning					
Implementation Plan	99/00	(1/5 py)		Implementation Plan	02/01/00
Monitoring	99/00	(1/5 py)		Monitoring Plan	02/01/00
Reevaluation		(1/5 py)			04/ 00
Basin Plan Amendment	99/00	(1/5 py)			10/28/99
Implementation	02/03			Full Implementation	05/01/03

Table 7C. Detailed TMDL Tasks Schedule (next three years)

San Gabriel River – Metals

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	02/03	(1/10 py)(st)		Problems statement write-up	6/03
Numeric Target	03/04	(2/5 py)		Rationale for numeric targets	8/03
Source Analysis	03/04	(2/5 py)	$50,000	Write-up of source analysis	1/04
Allocations	04/05	(3/10 py)	$50,000	Numeric allocations and rationale	10/04
Implementation Planning					
Implementation Plan	04/05	(1/5 py)		Report	11/04
Basin Plan Amendment	04/05	(1/5 py)		Draft Basin Plan Amendment	6/05
Implementation					
Monitoring	07/08	(1/5 py)		Monitoring data and QA/QC	12/07
Reevaluation	08/09	(1/5 py)		Report of reevaluation findings	1/09

San Gabriel River – Coliform

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	00/01	(1/10 py)		Problems statement write-up	5/01
Numeric Target	01/02	(2/5 py)		Rationale for numeric targets	7/01
Source Analysis	01/02	(2/5 py)	$20,000	Write-up of source analysis	12/01
Allocations	02/03	(3/10 py)	$20,000	Numeric allocations and rationale	9/02
Implementation Planning					
Implementation Plan	02/03	(1/5 py)		Report	10/02
Basin Plan Amendment	02/03	(1/5 py)		Draft Basin Plan Amendment	5/03
Implementation					
Monitoring	04/05	(1/5 py)		Monitoring data and QA/QC	10/04
Reevaluation	05/06	(1/5 py)		Report of reevaluation findings	11/05

San Gabriel River – Lakes – Nitrogen and Effects

Tasks	FY	Staff Resources	Contracts	Products	Completion Dates
TMDL Development					
Problem Statement	01/02	(1/10 py)		Problems statement write-up	5/02
Numeric Target	02/03	(2/5 py)		Rationale for numeric targets	7/02
Source Analysis	02/03	(2/5 py)	$25,000	Write-up of source analysis	12/02
Allocations	03/04	(3/10 py)	$25,000	Numeric allocations and rationale	9/03
Implementation Planning					
Implementation Plan	03/04	(1/5 py)		Report	10/03
Basin Plan Amendment	03/04	(1/5 py)		Draft Basin Plan Amendment	5/04
Implementation					
Monitoring	05/06	(1/5 py)		Monitoring data and QA/QC	5/06
Reevaluation	06/07	(1/5 py)		Report of reevaluation findings	6/07